Concrete

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By HARVEY WHIPPLE, Editor Concrete

Roof Tile Trade Marks and Jealousies

CONCRETE roof tile of the residence types has never come quite into its own. Its manufacture and sale has been carried on with occasional success and in some instances with continued success. There is no apparent sound reason why it should not be used far more extensively. There is no question but it can be made to serve as a superior type of roof covering and with proper equipment and a developed market be produced in quantity at a price very low considering its value. It must be good concrete because it must not only keep out the rain but it must resist the slow forces of moisture and frost as disintegrating agents—sure, under such exposure to attack a concrete that is at all friable. It is lighter in weight on the roof than the usual grades fo slate or burned tile, not because it is lighter per unit, but because it can be made so accurately that lap joints are comparatively narrow and very little of the material is wasted in successive layers.

In spite of many potential advantages the conspicuous successes in its manufacture and sale are comparatively few. It is not hard to find what appears to be at least a partial explanation.

With certain exceptions—and the exceptions in this as in other instances tend to establish the rule—there is a notable lack of co-operative effect among the producers of tile or among the producers of the machinery with which the tile is made.

There has always been a gulf separating various producers of the equipment—petty jealousies, rivalries and conflicting contentions of superiority. This gulf has widened since the advent of automatic, large production machines.

This separateness of the industry has extended to the producers of the tile, among many of whom there has grown up a fostering of "trade secrets." There is no such barrier to real progress as this notion of self sufficiency begotten by a reliance on certain trade secrets.

The truth is none of the manufacturers know *enough* about their business. Not a man in the business but has something to contribute if all the trade secrets were tossed into the same pot and allowed to simmer together over a co-operative fire.

For several years the American Concrete Institute has been making an effort to get various factors of the concrete roof tile business together on a committee where they could develop and organize their combined experience and bring out of it certain recommendations which might remove certain of the special ills to which that branch of the concrete products business is heir.

Nothing happens. It is no secret that the real fundamental difficulty is an apparent inability or unwillingness to sink special trade marks and pet machinery prejudices and consider the problems which all in the industry have in common.

Two outstanding among these problems are the use of color and correct methods of curing.

If the industry had got its individual heads together when the first attempt was made to form a committee, both these problems might now have been whipped.

Are We to Know More About Crazing?

IT DOESN'T need the purely philanthropic mental slant to find a good reason for spending money in research. The value of research intelligently pursued is a dollars and cents value.

Dr. P. H. Bates of the United States Bureau of Standards heads a committee organized by the American Concrete Institute to study the causes and the avoidance of crazing in concrete. The committee is doing preliminary work—studying specific instances of crazing and specific instances—many of them more apparent than real—of its avoidance. The committee has yet to attack the fundamentals in a study which may require a good deal of time and labor—therefore funds. Funds will probably be made available as more contractors, concrete products manufacturers and cement manufacturers count the dollars and cents cost of not knowing the fundamental facts about crazing in reference to the appearance of the phenomenon on countless jobs. So far a good many craftsmen are "getting by" through strategic avoidance of rich mixtures and smooth surfaces. If crazing is an offense only to the eye—most offensive when the checked surfaces take up the accumulating grime of the years—this method of dodging the issue may answer very well. There are those, however, who believe that crazing is a mild but insistent force of destruction or perhaps the symptom of that ailment, and while beautiful rough textures are satisfying they merely wheedle us away from a plain line of duty in studying the fundamentals. Is crazing to be eliminated (not hidden) by some change in the cement or the aggregate or the water or by adding something to these ingredients or devising some new method of manipulation and curing? The knowledge certainly has dollars and cents value, but is involved in such a common difficulty that almost everybody seems satisfied to let somebody else solve it.

Three Interesting Construction Jobs on Conservancy Project

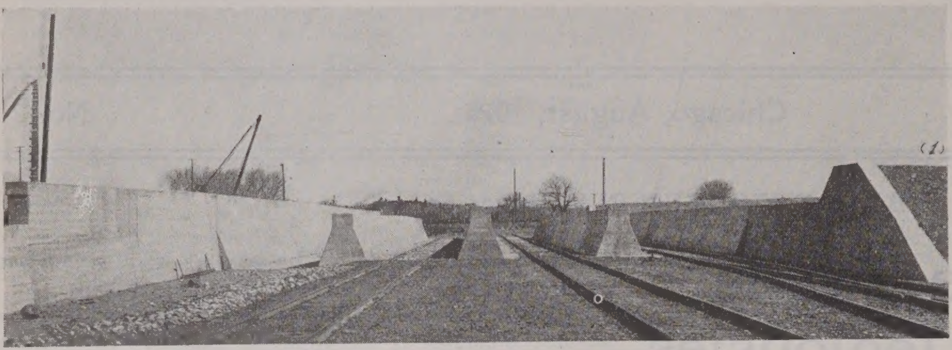
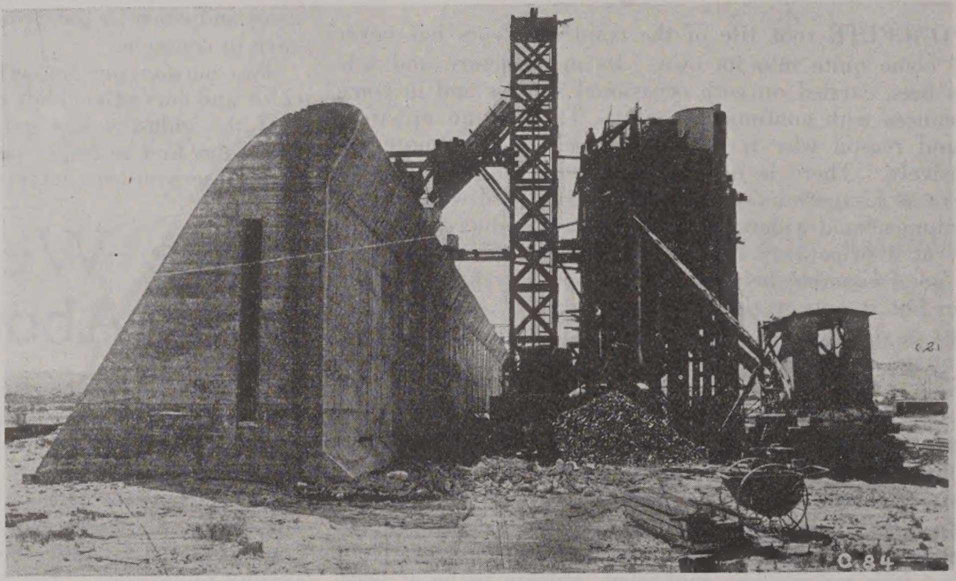


Fig. 1—Deck view of new type concrete railway bridge acrosss Dry Creek in the Conservancy Project at Pueblo, Colorado. The wall shown on the right in the picture acts as a retaining wall to protect the tracks from flood waters

Fig. 2—End view of section of concrete spillway of barrier dam at Rock Canyon near Pueblo. The Arkansas river and the Denver and Rio Grande Western railway pass through notches left in the dam



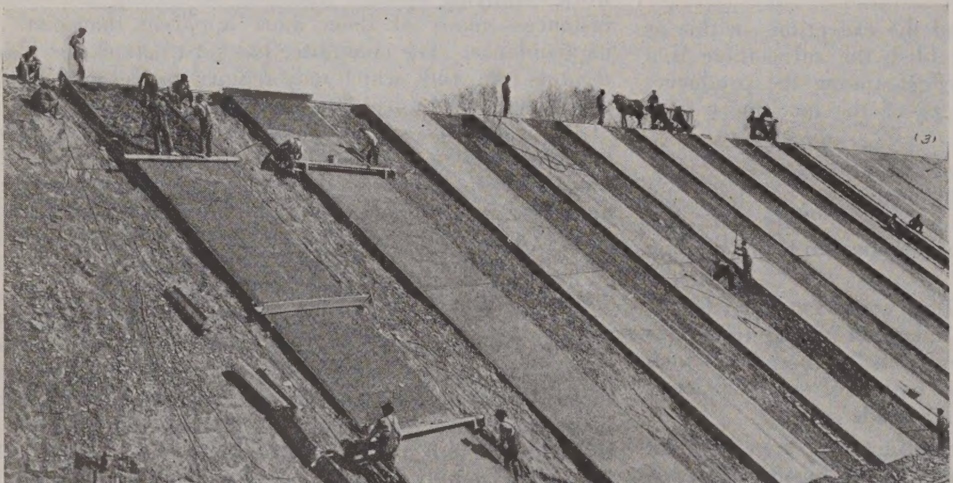


Fig. 3—Paving the levee slopes of the new channel of the Arkansas river for a length of 2.4 miles through the city of Pueblo. The levee has a slope of 1 1/2 to 1

Wide Use of Concrete in Conservancy Project

By EARL C. McCAIN

Three interesting pieces of construction are included in the following article describing the part played by concrete in the conservancy work in the vicinity of Pueblo, Colorado. Recognizing in concrete the principal agent in making Pueblo safe from flood, the engineers and directors of the Conservancy district took every precaution to insure that the concrete was properly mixed, placed and protected at all times.

The Dry Creek bridge was built with one girder or wall to act as a dam or retaining wall to protect the tracks from high water in flood time. This obviated the necessity of building a bridge deck high enough to clear flood levels and making trains climb steep grades to approach the bridge.

A concrete spillway together with a large earthen dam form a basin capable of impounding flood waters to a considerable height before the spillway comes into use.

A levee about 2½ miles long through the city was paved with concrete in the form of 10-in. slabs extending from 6 ft. below the channel bed to the top of the slope and surmounted by a 3-ft. guard curbing on top.

Concrete has had an important part in making Pueblo, Colorado, safe from flood and in preventing a repetition of the great disaster of June 3, 1921, when a sudden rampage of the Arkansas river cost more than 100 lives and destroyed property valued at $20,000,000. In the big $4,000,000 flood preventing project now nearing completion at Pueblo, concrete has made possible the construction of a great railway bridge that must stand directly in the path of floods; it is the principal factor in the construction of a gigantic spillway dam above the city, and it forms a great, unbroken line of levee slope paving that extends for a distance of 2.4 miles through the city to guard it from flood.

Dry Creek Bridge

Perhaps the most unusual use of concrete in the flood prevention project is in the construction of the Dry Creek railroad bridge. This consists of five huge 40-ft. spans, and is built entirely of reinforced concrete. Ordinarily, in spanning a stream that is subject to flood, the object is to permit the flood to pass under the bridge. But since four main line railroads had to pass over the bridge and the railroad engineers refused to approve a plan calling for sufficient elevation to be above flood height, the engineers faced the problem of constructing a bridge that would be safe from flood and yet directly in its path.

The railroads and the stream to be spanned enter the city at right angles. Owing to the restricted elevation of the bridge above the stream the engineers were convinced that a steel bridge would never be able to resist the terrific lateral pressure in time of flood. But they knew that reinforced concrete would resist this strain. This led to the designing of a bridge that would serve as a barrier dam and at the same time would not require trains to climb a steep grade to pass over it.

The bridge is supported by four narrow piers and two abutments, the piers offering little resistance to the water. The bridge has no expansion joints except two sliding joints located at the seats of the abutments, composed of zinc plates ⅜-in. and ⅝-in. thick. The floor of the bridge is 7 ft. above the level of the stream and it is estimated that it will scour 10 ft. deeper in case of flood. It will care for 25,000 cu. ft. of water per second, which is considerably more than is expected ever to come down the stream.

On the bridge deck and at right angles to the piers are girders separating the tracks carried. From the piers and

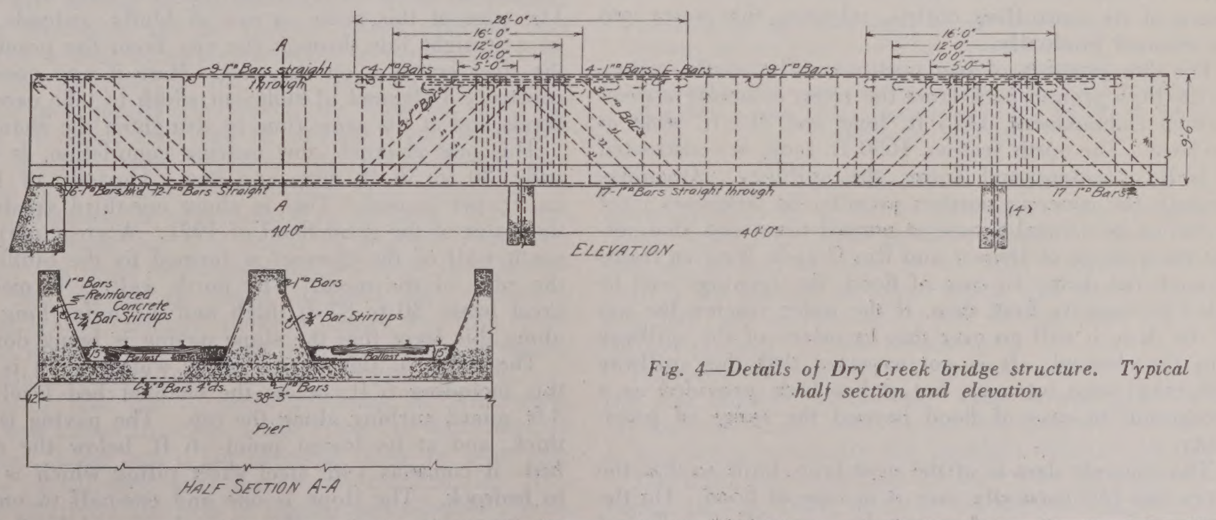


Fig. 4—Details of Dry Creek bridge structure. Typical half section and elevation

abutments steel rails extend through the floor of the bridge and into the girders, thus tying the whole structure together. The north girder, on the upstream side, is 12 ft. above the level of the tracks and is 21 in. thick. It is this girder that must act as the first barrier dam in case of flood, keeping the water off the tracks though it is above the track level.

The tracks passing over the bridge are laid on a cushion of ballast above the bridge floor. So solidly has the structure been built and so well is it tied together by reinforcing steel that the heaviest mountain type locomotives do not affect it.

The total cost of this railroad bridge is $110,000. It contains 5500 cu. yds. of concrete and 450,000 lbs. of reinforcing steel. In constructing it a tower 126 ft. above the floor level of the bridge was used. Movable chutes constructed on a truss supported by the falsework of the bridge carried the concrete from the tower chutes to the forms. The bridge was designed by the Dayton Morgan Engineering Co., which has charge of the conservancy work, with the co-operation of Herbert S. Crocker, of Denver, consulting engineer for the railroads.

An interesting feature of this bridge is that it was so designed as to permit the city of Pueblo to build a concrete highway bridge onto the north side of the railroad bridge, thereby greatly reducing the cost to the city. This was accomplished by extending the north end of each pier and abutment beyond the north wall line of the railroad bridge, thus forming ledges. Directly opposite each ledge the city sunk concrete column piers. The highway bridge rests on these ledges and column piers. This highway bridge, 280 ft. long and with a 20-ft. driveway, cost only about $16,000, and has the same approximate strength as the main bridge against which it is built.

Rock Canon Spillway Dam

Perhaps the most interesting sight in the entire Conservancy district is the great spillway and barrier dam at Rock Canon, six miles up the Arkansas river from the city. Here a great dam 3000 ft. long and ranging from 33 to 70 ft. in height extends like the Great Wall of China from the bluffs on the north side of the river across the stream and the intervening valley to a high mesa on the south side, forming a great basin that is capable of storing 900,000,000 cu. ft. of water.

While the barrier dam is a part of the Conservancy project and is included in the total cost, it is really separate from the main project of changing the river channel through the city. Its purpose is to store up the excess water coming down the river in case of flood, and by means of its controlling outlets, releasing this water into the channel gradually.

The dam consists of two portions. The south section, on the high ground back from the river, is merely a great earthen embankment, 1475 ft. long and 210 ft. wide at the base. The north section, 1650 ft. long, is constructed of solid concrete and forms the spillway. Openings through the concrete portion permits the Arkansas river to follow its natural course at normal times and also permit the passage of Denver and Rio Grande Western trains through the dam. In case of flood, the openings will be filled to capacity first, then, if the water reaches the top of the dam, it will go over this by means of the spillway into the channel. It is not expected that this spillway will ever come into use, but it has been provided as a precaution in case of flood beyond the range of possibility.

The concrete dam is of the ogee type, built so that the water can fall naturally over it in case of flood. On the basin side is an overhanging lip, providing sufficient width for the top of the dam with a great saving in concrete by not building from the base upward to the top of the dam. The railroad notch in the dam is 31 ft. wide and the river channel notch is about 30 ft. wide. These two permit a capacity of 40,000 second feet before any water is retained by the barrier dam.

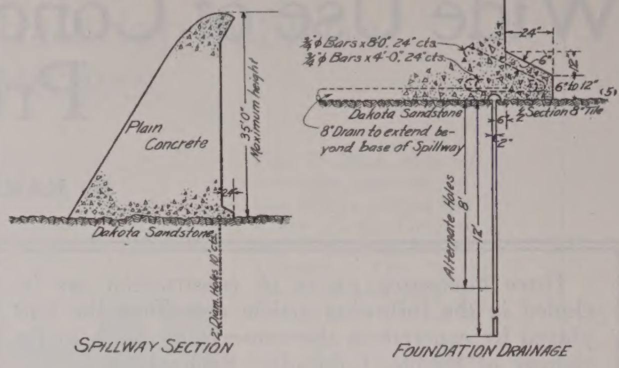


Fig. 5—Details of concrete spillway section of barrier at Rock Canyon, Pueblo Conservancy District

The total cost of the spillway and earthen dam is $300,000. The spillway portion contains 25,000 cu. yds. of concrete. In constructing it a Blaw-Knox movable steel form was used, with a 21-ft. concrete mixer. A plant built beside the dam carried the concrete to the top of the dam, where it was carried by means of tractors and steel dump cars on tracks along the top of the dam to the forms. It was necessary to cast each section in two or more pours in order to prevent too much pressure on the forms. At average intervals of every 10 ft. drainage holes, with tile outlets, are provided in the rock below the dam to prevent water collecting in the sandstone foundation.

Levee Slope Paving

The main contract of the entire Conservancy project is the new river channel through the city. The flood of 1921 had demonstrated that the old channel 150 ft. wide and with a capacity of only 35,000 cu. ft. per second, was inadequate to cope with flood conditions. The fact that huge industrial plants and business establishments stood on both sides of the stream made it impracticable to widen the old channel.

The southern residence section of the city stands on a high mesa, about 50 ft. higher than the level of the river. The edge of this mesa—a row of bluffs—extends almost on a straight line through the city from the point where the river enters it on the west. Here it was possible to construct a channel of sufficient width to take care of all floods and at the same time to straighten the channel.

This new channel, now nearing completion, is 265 ft. wide, 30 to 36 ft. deep and has a capacity of 125,000 cu. ft. per second. This is about one-third greater than the water of the great flood of 1921. A great part of the south wall of the channel is formed by the bluffs along the edge of the mesa. The north wall is formed by a great levee, 30 to 37 ft. high and 2.4 miles long. It is along this levee that the slope paving is being done.

The width of this paving at its widest point is 68 ft., this including 6 ft. below the channel bed level and a 3-ft. guard curbing along the top. The paving is 10 in. thick, and at its lowest point—6 ft. below the channel bed—it connects with steel sheet piling which is driven to bedrock. The slope is one and one-half to one, with an expansion joint in the natural ground level to take care of any settling of the levees. A total of 80,000 sq. yds. of concrete was required for the slopes.

In paving the slopes, forms were first tried, but found to be unsatisfactory. The method adopted was that of paving alternate 10-ft. sections, triangular-shaped "keys" being left in each section. The concrete of the intervening sections, filling these triangles, fastens the whole together. The expansion joint is in the form of an inverted V, which in case the upper section settles, merely closes the gap without cracking the concrete.

The necessity for this expansion joint was one of the lessons learned early in the Conservancy work, when some paving was done before the levee had thoroughly settled. However, very little difficulty from cracking has been experienced. The back slope of the levee has a slope of two to one and is not paved.

On the levee slope work, two modern 21-ft. pavers are used. These are placed behind the levees, it being found that the width of the levee top, 8 ft., was insufficient for consistent operation with the mixers on it. The concrete is hauled to the top of the levee where it is to be used. Chutes are used to carry it down the slope to where it is needed, in order to avoid loss in concrete in running it over the loose earth. The total cost of the levee slope paving is $560,000.

The engineers have required the contractors to waterproof all miscellaneous concrete structures that come in contact with the levees. The water in this section of Colorado carries alkali, which, coming in contact with the concrete, will affect the steel used in reinforcing. To offset this, a solution composed of 16 parts coal tar, 4 parts cement and 3 parts coal oil, is applied hot and in two coats to the concrete.

After the levee slope paving is laid, the concrete is kept wet for 28 days by means of perforated water pipes which send running water over it. This is to permit the water in the concrete to crystallize. Realizing that concrete is the principal agent in making Pueblo safe from flood and having selected it wherever possible because of its endurance the directors of the Conservancy district as well as the engineers have taken every precaution to see that the concrete is properly mixed, placed and protected at all times.

Making Drain Tile Resist Alkali and Peat Soil

The alkali investigation in the Northwest must eventually give some clue to the cure or avoidance of this particular destructive agency in connection with concrete. Sixty stout crates, each containing 50 2x4 in. concrete cylinders, were raised from the bed of Medicine lake in eastern South Dakota recently by S. H. McCrory, chief of the agriculture engineering division of the United States Department of Agriculture; E. V. Willard, commissioner of the Minnesota State Department of Drainage and Waters, and D. G. Miller, drainage engineer, in charge of the drain tile laboratory of the University of Minnesota. Every cylinder was closely examined by the men and all but 500 were again placed in the lake.

The 3,000 specimens represented about 125 different types of concrete, all made up at University Farm, St. Paul, for the purpose of perfecting a concrete drain tile which will endure in certain alkaline soils common to western Minnesota and the Dakotas. Each cylinder bore a number so that by reference to the corresponding number in the files kept at the farm information as to the quantity and quality of cement, the kind of sand, the amount of water, etc., used in making it can be readily found. Certain types of these specimens showed pronounced deterioration, while others were apparently as sound and strong as when placed in the lake. It is from a study of these that it is hoped to produce a concrete tile than can resist indefinitely the action of the alkaline salts. Best results are being obtained with specimens made of cement concrete specially treated and with specimens in which special cements have been used, according to an announcement from University Farm, St. Paul.

Medicine lake lies 17 miles northwest of Watertown, S. D., and about six miles south from the little town of Florence. Long ago it got its name from the large percentage of sulphate salts that its waters contain. It is fed by alkali springs rich in Epsom and Glauber's salts.

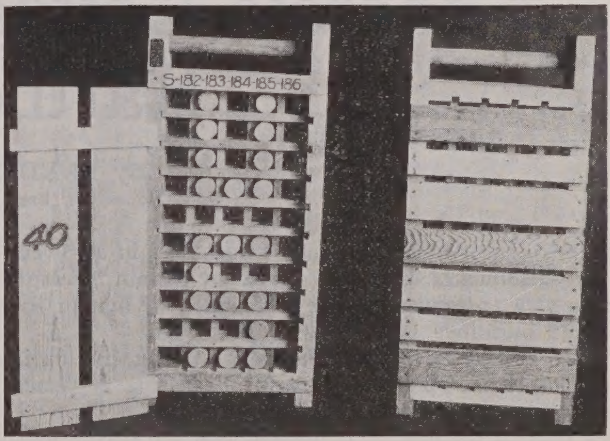


Fig. 1—Front and back views of the crates used to test out drainage tile materials in alkaline waters. Sixty of these crates, each containing 50 specimen cylinders of cement, have been immersed in the waters of Medicine lake in South Dakota for more than a year. This drainage tile work centers at University Farm, St. Paul

Other concrete cylinders, after being immersed at University Farm for more than three continuous years in an artificial solution, similar in character to the constituents of the salty lake, show no deterioration. These investigations, as well as those at the lake, will be continued until a tile mixture is found which will stand up under any and all conditions, if that be possible, says Mr. Miller, in charge of the laboratory.

Specimens of concrete tile are also being tried out in the peat lands of Minnesota. Tests in peat are now being made at Coon Creek, Grand Rapids and Karlstad. It is hoped that eventually this problem will also be solved.

The drain tile laboratory at University Farm was established July 1, 1921, under a co-operative agreement of the Department of Agriculture of the University of Min-

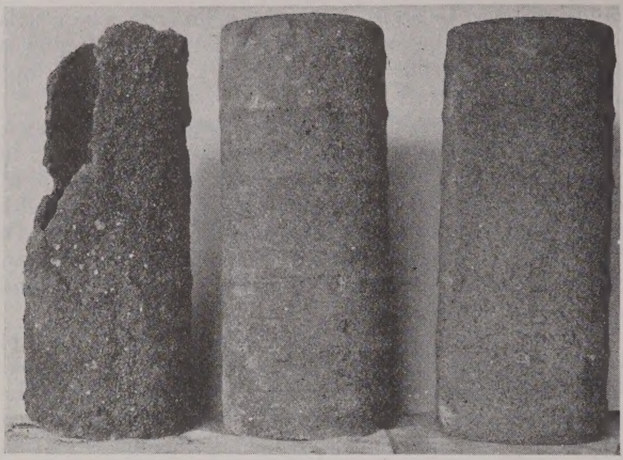


Fig. 2—Left to right—Tile lying in peat soil 11 years, tile in clay soil 11 years and tile kept in the stockpile 11 years and never used. The three specimens were made at the same time and from the same materials. From the co-operative experiments centering at University Farm a concrete tile that will endure indefinitely in peat soil is being developed

nesota, the Department of Drainage and Waters of the state of Minnesota and the United States Department of Agriculture. The direct purpose is to study the effect of so-called alkali waters on tile made of portland cement concrete and to produce tile which will have definite resistance and endurance. This work is of special interest to land owners of southwestern and western Minnesota, where tile failures in public ditches, resulting from alkali, were first noticed early in 1919, and which have continued to develop up to the present season in ditches constructed a few years ago. The results of this work also have far reaching application to many other sections of the United States where tile drainage is a factor in agricultural development.

Perhaps the most tangible evidence of what already has been accomplished by this work has been the fact that, so far as known, no failures due to disintegration have occurred in any public ditch in Minnesota in which tests or examinations were made, before construction, by the laboratory operations. This is due, says Mr. Miller, to the co-operation of the manufacturers in improving the quality of tile, and the readiness of engineers in availing themselves of the opportunities to make tests and soil water examinations as a part of the preliminary survey, thus making it possible to specify and obtain in advance the kind of tile to be used.

Combined with research, service work is performed in the laboratory by testing tile for engineers, manufacturers and individuals, and by examining for alkali, in order that proper materials may be specified, soil waters, submitted by engineers, in which the use of drain tile is contemplated. This service work assures a high quality of tile for use in both public and private ditches of Minnesota. In the public ditches alone more than 7,000 miles of tile have already cost more than $10,000,000.

Concrete Cottage to Withstand Earthquakes

By **FREDERICK RINGS**
Consulting Engineer, London, England

The design of houses and other buildings in areas subject to earthquakes should be guided by certain principles with a view to preventing the destruction of human lives and the buildings themselves.

There appear to be three distinctive movements during a shock period, viz: The upheaval or lifting movement, the creation of fissures and the oscillation.

As regards the first, it is obvious that the lifting movement may occur under the whole or any part of the building and in order to provide for the requisite resistance on part of the building the latter should rest on a raft foundation, that is to say the weight of the structure and its contents should be spread uniformly over the whole area of the ground occupied by the building instead of the wall foundations only. Furthermore, this raft foundation should be designed in such a manner that it can act in cantilever fashion if required and the structure itself should form part and parcel of the foundation being designed, in fact, as a box or series of boxes substantially tied together so that the whole structure can act as a beam.

The creation of fissures means the splitting of the ground under the building, the tendency of which is to split everything fixed to the ground. Foundations should, therefore, not extend into the ground but simply rest on the surface as otherwise the force acting in two opposite directions is bound to split the building and thus cause collapse.

The oscillation itself sets up torsional stresses and under these parts of the foundation walls and roof will be in rapid succession subject to tension compression and shear. This means that either surface area of the walls may be subjected to these stresses and the walls should, therefore, be designed as a series of columns reinforced to resist these stresses in every direction. The roof should be able to act as a beam in both directions. Under oscillation the principal stresses are then conducted to the angles of the building, viz: the junction of walls and raft and walls and roof, and these parts should be particularly strengthened and adequately tied together to the intent that the whole of the building in all its component parts oscillates at the same ratio, as one divided whole.

Earthquakes being always likely to cause fires, the building—or at least its external shell—should be composed entirely of fireproof material.

With special reference to the recent calamity in Japan it seems reasonable to presume that the authorities should endeavor to provide new housing accommodation of an improved kind at the earliest possible moment, and that a scarcity of labor and shortage of material would exist.

Under these circumstances it would appear an ideal proposition if fireproof houses were designed to resist oscillation and the other strains mentioned above could be manufactured and imported into Japan and they should be designed in such a way that they can be quickly put

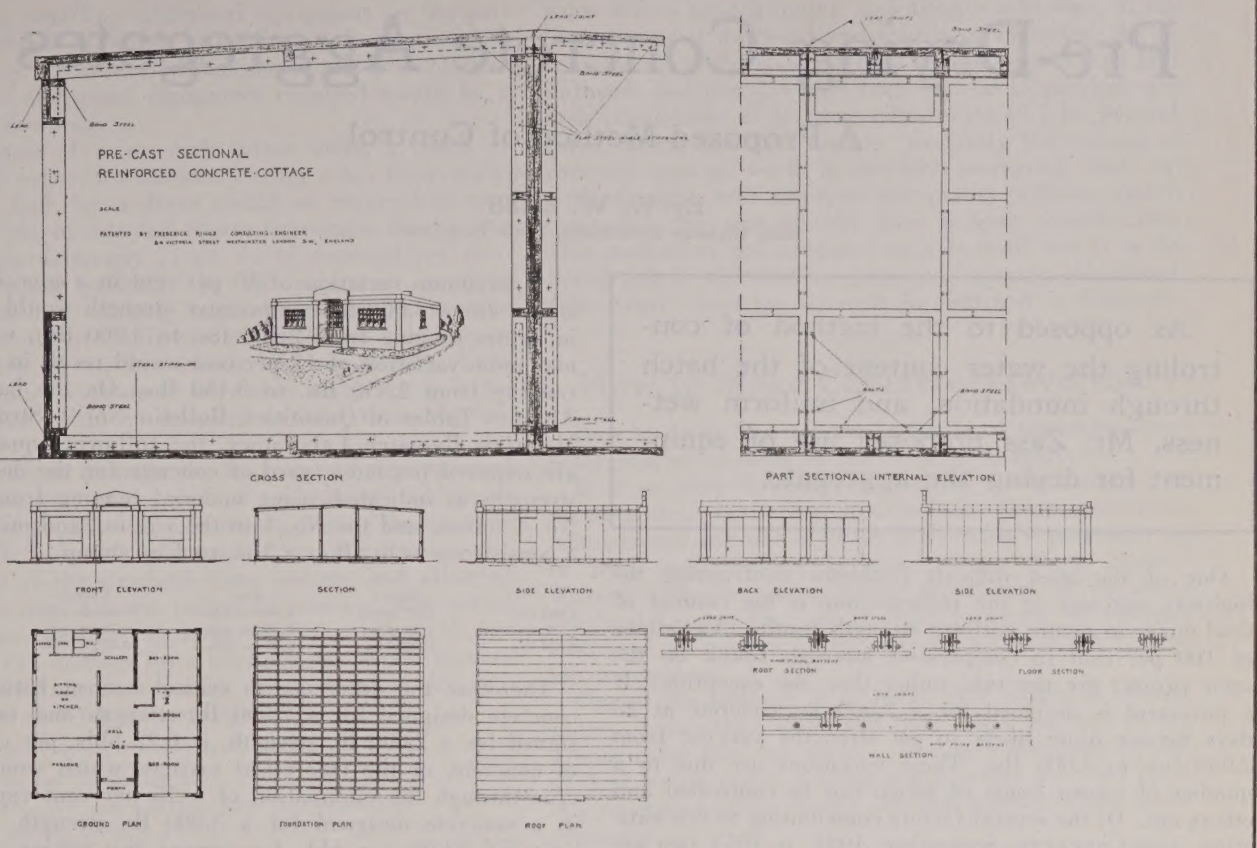


Fig. 1—Plans, sections and details of pre-cast sectional reinforced concrete cottage patented in England

up with unskilled labor and be ready for immediate occupation.

The writer suggests that his system illustrated by the accompanying drawings is the solution of all the difficulties prevailing. The house is manufactured in sections composed of concrete reinforced with steel and designed, when put together, to resist all the strains a building is subject to during an earthquake. The finished building is permanent and does not require any upkeep or future repairs whatsoever and is fireproof. Provision is made for fixing a suspended ceiling, an inner wall lining and a floor by simply nailing matchboarding to the fixing battens bolted to the concrete members of the outer shell. In this fashion a hollow space is created all around the building thus providing insulation against sudden changes in temperature and making the house comfortable at all seasons. The sections are bolted together and steel ties are provided to deal with the strains above mentioned. The joints, wherever exposed to external influences of water or damp, are made of lead which may be caulked in a hot or cold state. The bolt holes are formed in the manufacture and all bolts, nuts and washers are supplied with the sections, which latter are numbered, coinciding with a key plan so that the various members are easily identified.

The pressure on the ground is less than that caused by the weight of an average human body being about 1 cwt. per foot super, which is practically negligible.

The sections are manufactured at Purfleet on the river Thames, the site adjoining the river, so that they could be immediately transported to sea going steamers. The total weight of the sections for a cottage 30 ft. x 30 ft. is about 52 tons and that of the sections for a smaller cottage 22 ft. x 21 ft. is 31 tons.

As regards the ceilings and inner wall surfaces, these are suggested in boarding as the quickest and cheapest method but they may be of any material such as asbestos sheets and plaster or concrete slabs. The floors may be boarded as shown or filled in solid with weak concrete and finished with tiles or any other material required.

It will be observed that the houses may be enlarged at any time by adding further sections. When this is done the last bolts are unfastened and new sections added, the joints being easily removable.

All that is required to be done on the site, is to level the ground, put the sections in place and bolt them which can be done by anybody of average intelligence.

The internal finish consists simply of bolting down the fixing battens and nailing boarding thereto which again does not require skilled labor. Doors and windows, if required, can be shipped with the sections together with any modern conveniences and fittings that may be required.

Buildings of all kinds such as shops, railway stations, stores and so on can be easily constructed with the sections and permanent, shockproof, fireproof structures of all types erected with great rapidity.

If you have solved an interesting problem in concrete construction tell the Editors of CONCRETE. The information may help others in the field.

Pre-Drying Concrete Aggregates

A Proposed Method of Control

By W. W. ZASS
State Highway Commission, Little Rock, Ark.

As opposed to the method of controling the water content of the batch through inundation, and uniform wetness, Mr. Zass proposed use of equipment for drying the aggregate.

One of the most difficult problems confronting the highway engineer at the present time is the control of field mixes to secure uniform strength results. Variations of 100 per cent in compressive strength found on the same project are the rule rather than the exception. If a pavement is designed for a 3,000 lb. concrete at 28 days we are quite likely to get strengths varying from 2,000 lbs. to 4,000 lbs. These variations are due to a number of causes, some of which can be controlled and others not. Of the several factors contributing to this variation, (see CONCRETE, September, 1924, p. 105) two are largely conducive to the lack of uniformity, namely:

(1) The variation in water content per batch, due either to lack of control or to the variation in moisture content of the aggregates, or to the variation in volume of the aggregates received per batch.

(2) The variation in volume of materials per batch due to methods of measuring or moisture content of aggregates.

A significant fact when comparing results obtained from laboratory tests with results obtained from field tests is the uniformity evident in the laboratory results, and the non-uniformity prevalent in the field results. The uniformity evident in the laboratory results is, of course, the result of the exact methods followed. It is therefore reasonable to presume that if these laboratory methods were followed more exactly in field procedure a greater uniformity would result in our finished product. If a greater uniformity can be obtained in the field through the use of more refined methods in preparing and proportioning aggregates it is obvious that these refinements should be adopted, if the unit costs for labor and equipment increased through the practice of such refinement are equalled or offset by a decrease in the quantity and cost of materials used.

If, in designing a 3,000 lb. concrete for field use, we are assured of obtaining a concrete with a variation within 15 per cent of a variation within 30 per cent of the designed strength, we are in effect obtaining a concrete which has for all practicable purposes an assumed greater cement content. This assumed greater cement content would amount to the difference between the cement content required in the concrete of the higher variation and the cement content required in the concrete of the lower variation. It is an assumed quantity but would be an actual quantity if a concrete were being designed for a compressive strength for the variation indicated.

A maximum variation of 30 per cent in a concrete designed for a 3,000 lb. compressive strength would result in values ranging from 2,100 lbs. to 3,900 lbs., while a maximum variation of 15 per cent would result in values ranging from 2,550 lbs. to 3,450 lbs. On the basis of Abram's Tables of Quantities, Bulletin No. 9, Structural Materials Research Laboratory, the following quantities are required per cubic yard of concrete for the designed strengths as indicated, using material ranging from 0 to No. 4 screen, and the No. 4 to the 1½ in., and mixed to a consistency as to allow a 3 in. to 4 in. slump.

	Cement	Fine	Coarse	Mix
2,000 lbs.	1.17 bbls.	0.42 cu. yds.	0.69 cu. yds.	1-6.4
2,500 lbs.	1.39 bbls.	0.37 cu. yds.	0.72 cu. yds.	1-5.3
3,000 lbs.	1.68 bbls.	0.35 cu. yds.	0.72 cu. yds.	1-4.3

Therefore the difference in cement content between a concrete designed for a 2,500 lb. strength and one designed for a 2,000 lb. strength, is 0.22 bbls. per cu. yd. of concrete, or the theoretical savings, which would accrue through the elimination of a 15 per cent variation in a concrete designed for a 3,000 lb. strength. At a price of $3.00 per bbl. for cement this saving would amount to 66 cents per cu. yd. of concrete, or approximately 12 cents per sq. yd. of pavement, using the standard Bates section as a basis of computation.

As previously stated, laboratory tests, through the uniform results obtained, have proven the value of a uniform water content per batch as well as an exact volume of materials. That it is difficult, if not impossible, entirely to control these factors under present methods of field practice must be admitted. If the aggregates used were uniform either in moisture content or lack of moisture content no difficulty would be experienced in the control of the water content per batch, or in the quantity of materials delivered per batch due to the moisture content of the aggregates.

As a method of controlling the two factors mentioned, which contribute so largely to the variation discussed, a radical departure in present day methods is suggested, namely, that the concrete aggregates be mechanically dried before being proportioned and used. Upon first thought this would seem a gigantic task but further reflection indicates that the problem is not without precedent, although not in the concrete field, except on a small scale for cold weather work, but is required for any type of bituminous paving work. Generally speaking, the drying and proportioning plant for cement concrete aggregates would require triple the capacity required for a plant for drying and proportioning aggregates for bituminous paving work, the general relation of the depth of cement concrete paving to the depth of bituminous surfacing being as six to two. This ratio would not be exact, the density of the bituminous mix being greater than that of the cement concrete, but for the purpose of comparison being sufficiently exact. Neither would it be necessary to heat the cement concrete aggregate to the temperature to which bituminous concrete aggregates are commonly heated, but only to a temperature sufficient to remove the moisture content. Pre-drying coarse aggre-

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[1] "How to Get Uniformity in Road Concrete," by W. W. Zass.

gates would necessitate that all materials be mechanically handled, thus entailing additional equipment on the part of the contractor. However, as the materials on most fair sized jobs are mechanically handled at the present time the principal additional equipment required would be a dryer and accessories.

On the basis of a six sack mixer using a batch of 1:2:3½ mix every two minutes during a ten hour working day, we find that a dryer would be required to turn out 370 cu. yds. of fine and coarse aggregates during that period or approximately 17 cu. ft. of material per minute. This would probably be the maximum required under present day working methods, and under average conditions would probably run about 25 per cent less or approximately 13 cu. ft. of materials per minute. Even this latter figure appears to be rather high, but it is believed a dryer would be designed to meet these requirements.

It is difficult to estimate the first cost of this required equipment, as well as the cost of maintaining and operating it, but a rough estimate follows, basing the estimate on a ten-mile piece of work containing 105,600 sq. yds. of pavement of the standard Bates section, and allowing 100 working days for the period of placing. The actual working time, basing the same on an average of one batch every two minutes for a ten-hour day would amount to only 72 working days but for the purpose of this estimate we will use the greater figure.

Estimated first cost of dryer and accessories	$8,000
Estimated depreciation per annum	25%
Estimated operation cost for working day	30

UNIT COST FOR DRIVING AND PROPORTIONING

Interest on first cost per annum at 6%	480
Annual depreciation at 25%	2,000
Operating cost, 100 days at $30	3,000
Moving in and out and changing setups	1,000
Total annual charges	$6,480

Cost per square yard of pavement—$6,480 + $105,600 = 6.1 cents.

This unit cost would be increased or decreased, depending on the size of the job. It is obvious that it would hardly be economical to use such equipment where the estimated unit cost exceeded the assumed savings due to reducing the range in variation of the designed strength.

Where the coarse aggregate contains but a slight percentage of fine material, or is of a formation which allows but little variation, if any, in moisture content, it would be possible to dispense with running the coarse aggregate through the dryer, thus reducing the required capacity of the dryer about 60 per cent. Under these conditions a dryer as ordinarily used in a portable plant for asphalt work would meet the requirements in regards to the desired capacity.

A summary of the probable advantages accruing from the proposed method of pre-drying the aggregates may be noted as follows:

(1) Uniform water content may be used per batch.
(2) Exact quantities of materials can be measured per batch either by weight or by volume.
(3) Resulting in a concrete of uniform consistency.
(4) Resulting in a concrete of more uniform strength ratio.
(5) Possibility that paving laid in late fall or early spring would not be subject to "first warm weather expansion" to as great an extent as if aggregates used were of non-uniform temperatures varying widely in range.
(6) Possibility of paving laid with aggregates of nearly uniform temperatures expanding and contracting more uniformly, on the theory that the initial setting up processes within the slab vary in time and extent as to the temperature of the aggregates.
(7) The yield of mixed concrete per batch would remain more nearly constant, relieving the contractor of added costs due to overruns in cement content.
(8) The many advantages accruing in the field, from the point of view of the concrete worker, in having a concrete of unifrom consistency and workability.

The method proposed of pre-drying concrete aggregates before proportioning and using would seem at this time somewhat awkward and expensive; however, the developments in the concrete field in the past decade both in theory and practice have been such as to preclude any rash predictions as to what refinements will be promulgated during the next decade. Certainly the volume of concrete paving work is steadily increasing and any method which will improve the quality without unduly increasing the cost should have serious consideration. This method is not proposed as a cure-all but it is believed that it will tend to produce a concrete which will more nearly meet the strength for which it is designed.

How to Make Concrete Travertine

How to make the concrete fascimile of travertine stone is the subject of more or less frequent inquiry.

It is so very largely a matter of workmanship that *seeing* it done is the best first lesson. There are several methods and not one of them is so exact a procedure as to lend itself readily to description. From Samuel Warren, manager, Atlas White department of the Atlas Portland Cement Co., one of those to whom we recently addressed an inquiry on the subject, we have the following suggestions:

One of the methods is to make glue molds of several pieces of travertine stone and then cast a mixture of the proper color into this mold. The only objection to this method is that unless a great many molds are used there is a repetition of the design and this method is also quite expensive.

Another method is to make up the mixture of proper color and apply it like a stucco coat, but with the mixture very dry, and put on in irregular lumps so that when it is trowelled smooth imitations are made of those peculiar holes that are in natural travertine.

Another method is to incorporate pieces of string in the face of the work and after the work is partially set pull these out, thus breaking out irregular pieces of the finish.

Another method in making cast slabs of imitation travertine is to sprinkle the face of the mold with calcium carbide. When the mixture is put into the mold, the water causes bubbles of gas to form, which gives an effect similar to the holes in travertine.

The color of travertine is a greyish yellow and can be reproduced by using white portland cement, sand of greyish color and yellow ochre.

But whatever method, it is a matter of skill and workmanship.

Bibliography on Portland Cement

A bibliography on portland cement has just been prepared by Prof. Duff A. Abrams, Structural Materials Research Laboratory, Chicago, Ill., which refers primarily to portland cement and does not include the voluminous literature on concrete and reinforced concrete. Detailed bibliographies are contained in many of the papers mentioned and it is suggested that periodical literature should be consulted for recent developments.

A list of text books is given in which more complete reference lists on certain subjects may be found. Various periodicals with the address of the publication office are named. The bibliography is arranged under the following headings: Historical; General Treatises, Raw Materials and Manufacture; Physical Properties and Tests; Chemical Properties and Constitution; Specifications.

The Design of Cement Concrete Pavements

By A. T. GOLDBECK
Chief, Division of Tests, U. S. Bureau of Public Roads

THERE are many papers about concrete roads—expressions of individual experience and opinion—work of unusual character or by unusual methods. This one by A. T. Goldbeck goes over the matter of concrete road design from the fundamentals upward and in its clear, straightforward review of these fundamentals should appeal to many roadbuilders, whose particular job in hand has kept them out of earshot of much of our rapidly widening knowledge of the hows and whys of concrete road behavior in use. The paper is cut in two parts—the second part in the next issue of this magazine.—Editor.

Although there are several other phases to the design of cement concrete pavements, the present discussion will be confined to that dealing primarily with the design of the pavement from the structural standpoint. The concrete pavement considered as a structure would not be complete without the inclusion of the underlying subgrade, for from the results of investigation, theory and practical experience it has been shown that the subgrade portion of the structure greatly influences the behavior of concrete surfacing. From the very outset, therefore, it will be important to consider some of the properties of the various types of subgrade materials upon which concrete roads are laid.

The Subgrade

When the wide variety of geological conditions under which soils have been formed on the surface of the earth is considered, it is easy to understand why these soils differ so radically in their characteristics. Much of this material is the result of disintegration and weathering of surface rock formations varying through the many varieties of sedimentary metamorphic and igneous rocks whose chemical and physical structures vary widely. It is but natural that the resulting products of disintegration, the soils, should possess marked differences in their physical and chemical properties. Many soil formations have resulted from the grinding and conveying action of the vast sheets of ice whose periods of activity probably extended over hundreds of thousands of years. Other soils have been water-borne and later deposited while still others have accumulated through the carrying action of strong winds. Thus, throughout the United States we are forced to build highways on soils varying from highly plastic clay to solid rock with every conceivable intermediate variation. The subgrade is the foundation from which we are building our concrete highways and with the visible evidence of such wide variations in character it is incumbent upon us as engineers to satisfy ourselves as to the nature of that foundation and as to the possible effects it is going to have on our pavement structure.

Physical Tests of Subgrade Materials and Their Significance

During the past three or four years we have been developing standard tests for subgrade materials in order that we might analyze soils from prospective road locations and determine whether or not any special precautions might be necessary. It is not my intention to go into complete details of these analyses at the present time, for the test procedure has been described elsewhere.[1] The tests which are performed have been designed because of the particular significance which the results have from the road subgrade standpoint. They are listed as follows:

1. Mechanical analysis.
2. Percentage of capillary moisture.
3. Moisture equivalent.
4. Dye adsorption.
5. Slaking value.
6. Moisture capacity.
7. Comparative bearing value.
8. Shrinkage value.

1. *Mechanical Analysis.* This consists of determining the percentage of the particles of various sizes, a sample being roughly divided into clay, silt and sand. By clay, we mean that portion of the soil which will remain in suspension in water after separating and allowing to settle for eight minutes. By silt, we mean that portion of the sample which may be washed through a 200-mesh sieve and which will settle in a period of eight minutes after agitation with water. Sand is that portion which is retained on a No. 200-mesh sieve but which passes a No. 10-mesh sieve. Soils which have a high percentage of clay are generally of a very undesirable character requiring special precautions in the pavement design. Such soils are apt to be very plastic when wet and therefore have very little bearing value. They are apt to swell considerably upon taking up moisture and shrink upon drying out and therefore offer non-unifrom support for the road surface; moreover, because of the large amounts of water which they are able to hold they are dangerous owing to excessive heaving in times of cold weather. On the other hand, it is quite characteristic that the higher the percentage of coarse particles such as sand, the more the above undesirable characteristics disappear, and the better are the results to be expected from the sandy or granular types of subgrade.

2. *Per Cent of Capillary Moisture.* The amount of water which soils are capable of absorbing through their capillary action is important, for ordinarily the road surfacing is not built up to any great extent above the water table and, moreover, the pavement itself serves as a preventive against evaporation. Thus in time the soil takes up considerable moisture by capillarity from the underlying layers and this becomes a potential source of harm. Soils having low capillary moisture content are desirable soils for subgrades.

From a paper presented at the Eleventh Annual Conference on Highway Engineering at the University of Michigan, Ann Arbor, February, 1925.

[1] Proceedings A. S. T. M., Vol. 22, 1922—"Physical Properties of Subgrade Materials," by J. R. Boyd.

3. *Moisture Equivalent.* A test which has been developed by agricultural physicists is the so-called "moisture equivalent" test. In this test the soil sample is first saturated with moisture and is then placed in a centrifuge and whirled so rapidly that a force is developed on the sample equal to 1000 times its weight. This high centrifugal force acting on the contained moisture tends to draw it away from the sample through the orifices in the container. Considerable moisture remains notwithstanding this high centrifugal force, and the percentage of moisture retained in the sample after a period of one hour of this treatment is known as the "moisture equivalent."

Apparently this test is quite indicative of the probable behavior of a soil when used as a road subgrade, and if there is any one test which is more indicative than the others perhaps the "moisture equivalent" test is most important. The values from this test range from a very low per cent for sandy materials up to perhaps 50 or more per cent for very plastic clays. There seems to be good reason for believing, tentatively at least, that it is not particularly safe to build pavements on soils having a "moisture equivalent" higher than approximately 20 without giving serious consideration to the necessity for taking special precautions in the pavement design. It is interesting to note in this connection that it is quite possible to determine the "moisture equivalent" value of soils by means of a simple field test with no elaborate equipment. This test has likewise been described elsewhere.[2]

4. *Dye Adsorption.* It has been discovered that when analine dye solution is filtered through finely divided soils the color of the dye disappears upon passing through the soil. A given amount of soil can only decolorize a given volume of dye and some soils possess this property more than others. Apparently the soil which can decolorize the largest volume of dye is apt to be the soil which is most plastic and which is most undesirable for subgrades. It often happens that the clay content in two soils is the same, but the clay portion has different characteristics, one clay being capable of decolorizing a far larger amount of dye than the other. Because of these different characteristics of the clay portions, the soils themselves behave in a radically different manner. A high dye adsorption value is indicative of a poor subgrade material.

5. *Slaking Value.* The slaking value test consists merely of determining the rate at which a soil will be disintegrated upon immersion in water. Soils vary greatly in this respect, some of them being almost impermeable, requiring a very long time to break up in water, others breaking apart immediately. The significance of the slaking value test is subject to further study, but apparently it has something to do with the rapidity with which the subgrade might be affected by moisture and also with the rapidity with which drying out might occur after saturation.

6. *Moisture Capacity.* The moisture capacity of the soil is determined by saturating the soil and allowing it to drain by gravity and determining the amount of moisture which remains. This value no doubt is tied in closely with the moisture equivalent and to some extent with the capillary moisture. Any interpretation of the results of the tests thus far made must be deferred until a better correlation is made with field behavior. In general, however, it might be said that the higher the moisture capacity of the soil, the less desirable is that soil for road subgrades.

7. *Comparative Bearing Value.* Since the subgrade supports the road it would seem that the ability of a subgrade to support loads without yielding should be an important characteristic. In the laboratory a test for comparative bearing value is made by slowly subjecting the prepared sample of soil to increasing load and observing the amount of penetration of the bearing area into the soil. Some soils yield under comparatively low load, others support high loads with very little yielding. Plastic clays are of the former type and well cemented granular soils of the latter.

8. *Shrinkage Value.* A very significant test of a subgrade soil is its amount of shrinkage upon drying out. Everyone has observed the wide open shrinkage cracks which form in the ground surface of a very plastic clay after it has been exposed to the sun and wind. Such cracks indicate very high lateral shrinkage and naturally, therefore, very high accompanying vertical shrinkage. Under conditions which make for high moisture content, a subgrade of this nature expands vertically and during times of dry weather the moisture evaporates and the soil shrinks. Owing to the more or less air-tight nature of a concrete pavement, it is natural that evaporation should proceed more rapidly at the edges of the pavement. Moisture samples taken from under roads in California have actually shown that less moisture exists at corresponding depths at the sides of the pavement than under the center. Higher vertical shrinkage is therefore to be expected at the sides than at the center, and it is not surprising that there are times when there is an actual separation of the subgrade from the pavement. Under these conditions long longitudinal cracks have resulted in concrete pavement surfaces 3 or 4 ft. from the edge. It is thus seen that the percentage of shrinkage of the soil is a most important factor and where a soil has a linear shrinkage factor greater than 5%, a special design of the pavement or a special treatment of the subgrade is very likely needed.

One of the most successful treatments for preventing the cracking of the concrete due to excessive shrinking of the subgrade is claimed to be the use of a layer of sand, rather loosely compacted about 4 in. in thickness, interposed between the subgrade and the concrete. In the construction of the Pittsburgh Test Road in California, which was a concrete road laid on an adobe subgrade, no cracking of the concrete occurred except under traffic, and in this case the subgrade was prepared through a depth of 3 ft. by plowing, spraying very lightly with water and re-rolling in layers of 6 in. It is possible that a modification of this method might be used successfully.

There is an extremely wide range of physical characteristics which subgrade materials possess, as shown in the results of a number of analyses made in the subgrade laboratory of the Bureau of Public Roads. Several attempts have been made to correlate the field behavior of pavements with the physical characteristics of soils. It will readily be understood that any exact statement of the characteristics of a bad soil as contrasted with a good one is almost impossible, for many factors and combinations of factors play an important part in causing the success or failure of any road, and it is sometimes difficult to separate the influence of these factors from the influence exerted by soil characteristics.

General observation on certain pavements has led to the somewhat tentative conclusion that if a soil has a "moisture equivalent" value in excess of approximately 20% or a lineal shrinkage value in excess of 5%, this soil is one which is apt to cause trouble, for it probably will be capable of retaining an excessive quantity of moisture which might soften the subgrade unduly and which will result in excessive movement due to frost

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[2] *Public Roads*, Vol. 5, No. 6—"Practical Field Tests for Subgrade Soils," by A. C. Rose.

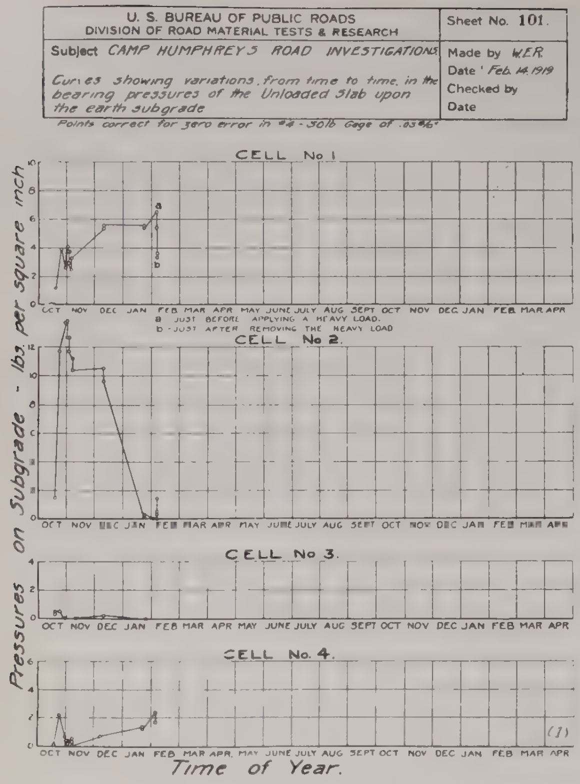


Fig. 1

action and due to the shrinkage of this soil upon drying out. With such subgrade special precautions must be taken with the design of the pavement.

Treatment of Bad Subgrades

If one of these precautions takes the form of a special subgrade treatment, the use of a layer of granular material such as cinders or sand, to a depth of approximately 4 in., seems to have given best results. The practice of so-called stage construction in which a sand-clay road or a gravel road is first built, to be later followed by the construction of a concrete pavement, is a form of subgrade treatment which is very valuable. Should a layer of granular material be used under a concrete pavement and, moreover, ample provision must be made to drain this layer in order that it might not become a reservoir for water under the pavement. Whether or not such a layer would be beneficial in climates where the frost penetrates 4 or 5 ft. into the ground is still very problematical and open to considerable debate, for should the frost penetrate to this depth there will be expansion of the soil due to freezing under the granular layer resulting in vertical motion of the pavement.

Moisture in the Subgrade

Probably one of the most important factors with which we have to deal in connection with the subgrade is that of moisture. Soils have very great differences in their ability to hold moisture and the effect of that moisture on the behavior of the soils of various types likewise varies considerably. Comparing the soils: one has a high "moisture equivalent" value, a large shrinkage factor, a high dye adsorption number a large amount of clay and a small amount fo sand; another has a low "moisture equivalent" value, a low shrinkage factor, a low dye adsorption number, a large amount of sand, together with a small amount of clay. The first would give trouble as a road subgrade, while the second would serve very efficiently for properly supporting the pavement with very little vertical movement.

So far as we have been able to determine, the moisture which exists under a pavement might arrive there (1) by percolation under a hydraulic head, in which case it becomes "free water," (2) by capillarity either vertical or horizontal, and (3) by evaporation from below and subsequent condensation immediately under the slab. Several interesting facts have been discovered as the result of investigations along this line conducted by soil physicists and by engineers of the Testing Division of the Bureau of Public Roads. One of these is that in times of low temperatures at the surface, the capillary tension is somewhat increased, resulting in the possibility of high moisture content through increased vertical capillarity. Another point which has been brought out is that in times of low surface temperatures there might be considerable condensation of vaporized moisture immediately under the pavement and such condensed water might actually become "free water." If the soil is of such a nature that "free water" renders it very soft, it is apparent how considerable damage might be done. It is likewise apparent how a layer of granular material might be valuable under these circumstances, for the characteristics of granular materials are changed but little by the presence of "free water." Another important observation which seems to be substantiated by test results is that tile drains are effective only in removing free moisture from the soil and that drainage systems cannot remove capillary moisture. This must not be interpreted to mean that tile drains are ineffective, for they are of considerable value in many locations where "free water" might do considerable harm.

From the foregoing it will be evident that the subgrade cannot always be counted upon to offer uniformly good support to a pavement slab due to its continuous movement from the expanding and shrinking action of moisture and due to frost. This is so, independent of other factors in the concrete pavement itself, which also make for non-uniform support. The writer has made measurements of actual pressures existing under an 8 in. concrete pavement. The measurements extended over a period of several months, and were found to vary from day to day in different portions of the slab. A curve illustrating this point is shown in Fig. 1.

Significant Characteristics of Pavement Concrete

We have considered some of the essentials of the foundation portion of a concrete pavement and in order to proceed further with the important features of pavement design we must now review those properties of the concrete which have control of the behavior of the pavement when it is subjected to the various forces of traffic to those of nature and those resulting from the inherent characteristics of the material itself. To understand what are the significant properties which road concrete must possess let us mentally observe the concrete from the minute it is deposited on the subgrade. Let us make a record of the forces which it meets and the properties which it must have to combat these forces successfully.

Almost from the moment the concrete is deposited on the subgrade it begins to stiffen and harden and immediately it is subjected to forces, the effects of which may or may not be immediately apparent. For instance, we are all familiar with the surface checking which sometimes results within a very short time after depositing, especially in times of hot weather and high winds. Concrete shrinks upon drying out and, in shrinking, cracks are formed at this early stage of hardening, for then the concrete has practicaly no strength. It is highly important that protective measures such as the use of a covering of wet burlap be used to combat this property of concrete

(Continued on page 44)

E. C. Lindsley of C. E. Lindsley Co., Inc., Irvington, N. J., is thoroughly sold on the value of a stockpile—the photograph from which this picture was made was issued in quantity with an attached circular carrying the message: "Showing stock on hand exceeding 122,000 blocks. It is of vital importance to every builder to know that we have a large stock of well seasoned blocks available to supply any job, whether large or small"

The Time to Plan for Next Year's Rush for Concrete Masonry Units

The time to prepare for a bigger volume of business in the early part of 1926 is in the latter half of 1925.

It takes a bigger factory and more machinery to produce a given number of building units in the eight months from March to October than in the twelve months of the year. Get more out of the machinery and spread the overhead over a year-round production.

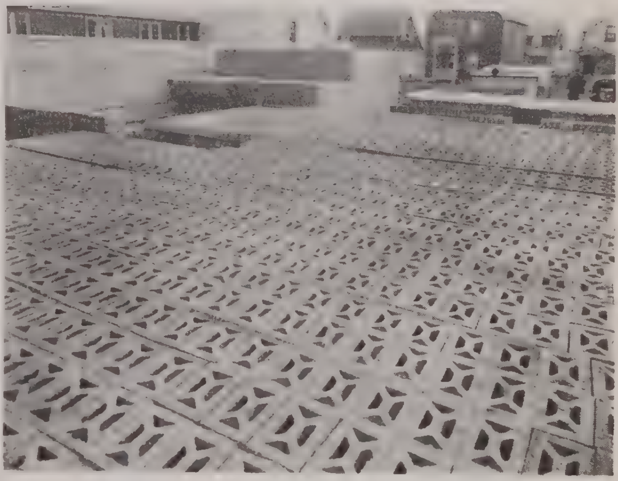
Readiness at the opening of the building year is an important consideration. That means stocks—stocks accumulated in the slack season.

Without plentiful stocks, other phases of the products manufacturer's business will be handicapped. With adequate stocks of well cured products he is prepared to go after business and to feel assured that his plant will be able to keep pace with demand and sales.

One of the remarkable features of the concrete products business has been the seeming reluctance with which manufacturers have undertaken winter work. Probably as many plants are boarded up in winter as remain open and producing. Then when spring comes and building begins the plants are opened and the feverish rush to supply an already insistent demand begins. It is in this method that many of the faults of the industry lie. Far too many products have been turned out in haste which might just as well have been made in time to cure properly

There are other advantages to having a full supply of products on hand. First, concrete products are a coming building material. In many places its merits have yet to be proved. It is subject to unfounded criticism and being new must prove its case. The plant which operates during the winter months even though under curtailed production finds in that period of the year a splendid opportunity to demonstrate to architects and builders the qualities of the product. These critics who largely determine the popularity of a material can be taken through the plant, shown the large stocks of well-cured products on hand awaiting their orders, and given a first-hand demonstration of the materials and care used in making the block.

There is no better method of advertising than this. There is also a psychological effect upon visitors in the orderly stocks of products. They seem to feel that here is a manufacturer who is only waiting their orders to supply them without loss of time with suitable materials. They become, in part, owners of the stocks.



In George D. Barriball's yard in Cleveland

The demand for concrete products is growing in every part of the country. We have only to consult figures for sales of products to verify this. In 1920 there were fifty million units made. Four years later, in 1924, four hundred and sixty-two million units were made and sold, a gain of more than 800% in four years. Does not this alone prove the adaptability and acknowledged favor of this type of building material?

Products men can well cast up their ledgers and see how near to this proportionate increase their sales were during the same period. If sales fell far short of this figure, then a manufacturer is not getting his rightful increase of the growing business in concrete building

E. P. Henry & Sons stockpile, Woodbury, N. J.

units. And this is only the beginning. Just as the past four years have seen enormous increases, so will the coming four years witness equal strides in production and sale.

If the manufacturer is to get his share of this business, he must be prepared for the rush season. It comes every year. And at the same time—in the spring. Through the winter, architects and contractors draw their plans for building; they put their client's ideas into buildable form and in the spring, the rush starts. It is physically impossible for any manufacturer to open his plant after the rush begins and then hope to get his share of the business.

But on the other hand by use of the months when building is slack, when contractors and architects are planning, he can lay by a stock of well-cured products which will carry him through the first rush days and allow him time to get his plant into full operation and to cure adequately additional units to keep pace with the spring demand. Only by so doing can the manufacturer become successful.

Some say that it takes money and operating funds which they do not possess. Have you talked the prospects over with your banker? Any banker who can be shown that there is a steady, recurring demand during certain periods of the year and which means rapid turnover, would be interested in loaning money. It may even be cheaper to borrow for operation than to build additional factory space and buy more equipment to increase the speed of production.

Seemingly, the manufacturer cannot lay by too many units. Instances are on record of stocks of 75,000 block being sold out before the real rush opened. But while this may be exceptional, it is true that surprisingly large stocks can be sold before the season opens. If you have the stock you can get the business, is almost the axiom of successful manufacturers. And spring business brings the profits.

The busy season is still on and at the first fall slackening is the time to make the decision as to continuous operation through the winter.

New Developments in Maintenance of Concrete and Brick Roads

By A. H. HINKLE
Superintendent of Maintenance, Indiana State Highway Commission
From paper before Eleventh Annual Road School, Perdue University

In this paper Mr. Hinkle, who has had long and thorough experience with road maintenance, discusses the newer practices in giving our hard road surfaces a longer life.

Large sums of money are being invested annually in the construction of concrete and brick pavements. It is important that the most economical means of maintaining and repairing such pavements be determined and put into practice in order that these large investments shall be protected. It is important that every type of road be properly maintained. Unless it is contemplated to care properly for the more costly types of pavement, we can not justify ourselves in building them.

Although the highways are now a controlling factor in our modern civilization and the transportation feature of them is the big development which stands out most prominently and is most impressed upon the general public, yet it is imperative that many little technical details be learned and put into practical effect in order to build and economically maintain a system of good highways.

Filling Cracks and Joints

Monolithic types of pavement are all subject to cracking. While these differ greatly in degree they are not necessarily any serious detriment to the pavement. Observation will show, however, that usually the more frequentlly the cracks are found the more defective is the concrete or the poorer the sub-grade.

The cracks and joints in such pavements should be sealed about twice a year so as to keep the pavement water-tight and thus prevent, so far as possible, water from reaching the sub-grade. Also, the cracks should be filled to prevent the edges from raveling.

Our experience would indicate that the most suitable material for filling such cracks is asphalt meeting our specification for Emulsified Asphalt A. E-1 or tar meeting our specifications for Tar T. P.-2. The former material is used cold while the latter has to be heated before it is poured into the cracks.

Both materials are covered with coarse sand, or stone or slag about ½ inch in size. The bituminous material can best be poured into the cracks from a small pouring can preferably not exceeding two gallon capacity. A small can will aid in preventing the use of too much of the asphalt or tar which is very objectionable. The use of an excess of the bituminous material will build up a ridge across the pavement which is quite as objectionable as the unfilled crack. In addition to the neglect to fill the crack, I know of no more frequent mistake than the persistent use of an excess of the bituminous material. The crack should be just filled with the asphalt or tar which should be permitted to lap over on the spalled edges of the concrete no farther than is necessary to merely protect same. Experience and observation will soon teach one how much material to use. After the filler has been subject to traffic for a few days, the crack filler should project above the level of the pavement no more than ¼ inch. The filling of the cracks can be properly done if a little care is used in the work. Too frequently the work is done with the grossest carelessness.

Because the filler is splashed out of the crack by traffic going over it just after it is poured, it is desirable on a heavy traffic road to fill the cracks in but one side of the pavement at a time. The filling operations themselves will keep the traffic off the newly filled cracks for a short time which is usually all that is necessary.

The repair of cracks in monolithic brick pavements can

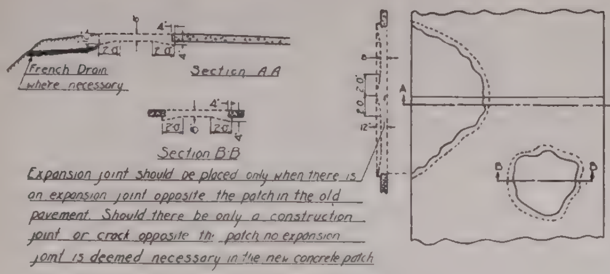

French Drain where necessary
Section A A
4'
20
Section B B
4'
20
12"
A
A
B
B
Expansion joint should be placed only when there is an expansion joint opposite the patch in the old pavement. Should there be only a construction joint or crack opposite th patch no expansion joint is deemed necessary in the new concrete patch

Diagram showing method of patching concrete pavement

be made in the same manner as cracks in concrete pavements.

Emulsified asphalt, if subjected to freezing temperatures before the water evaporates, will be injured and hence it can not be successfully used during the winter season. Very small cracks may be filled during the winter season, with cold tar meeting with our specifications for Tar T. C. M. This grade of tar cannot be successfully used to fill cracks in its pure state during the summer season as it is too liquid and will readily flow from the cracks.

Where the cracks are sufficiently wide the edges should be painted with one of the above grades of bituminous materials and then tamped full of bituminous concrete made by mixing either emulsified asphalt AE-1 or tar TCM with a graded stone. The maximum size of stone should be no greater in diameter than two-thirds the width of the crack or the depth of the depression to be filled and should be graded down to ¼ inch size. If tar is used to make the mix it should contain practically no dust nad little material that will pass the ¼ inch. If the asphalt is used, 10 per cent to 20 per cent of the stone may pass the ¼ inch and a small amount of dust is not objectionable. If there are visible voids in the mixture used to fill the cracks after same are tamped into the crack, they may be filled with a paint coat of the emulsified asphalt or hot tar TP-2 and covered with sand.

Surface Disintegration or Depressions in the Surface

Very shallow disintegrated areas may be painted with emulsified asphalt or the hot tar and covered with coarse sand or stone or slag screenings. If the depression is of any appreciable depth, after the surface is painted, it should be built up to the proper elevation by tamping into the paint coat one of the bituminous mixtures mentioned above. For this latter purpose rock asphalt or any one of the hot mix bituminous concretes may also be used.

In making such patches it is exceedingly important that the surface be brought to a true and uniform grade so as to have, when completed, a smooth riding surface. A straight edge should be applied parallel with the line of the traffic to aid in determining the smoothness of the surface. It is also important that no great excess of bituminous material be used in painting the old surface and that the minimum amount of the bituminous material be used in the mixture in order to reduce as far as possible the possibility of the surface waving and rolling under future traffic.

Sub-grade Defects—Base Failures

It is not uncommon to find the pavement failing because of a poor sub-grade consisting of clay which saturates badly by capillary attraction. This is frequently a difficult problem to solve. Every effort should be made to drain the sub-grade, as frequently springs are found in such clays. Besides having suitable side ditches, french drains can be constructed in the shoulders extending from about 1 foot below the lower edge of the pavement to the side ditches. If these fail to properly drain the sub-grade, the slab will frequently break up in time after much heavy trucking has gone over it. These breaks produce what are known as a "base failure." Such failures frequently can not be prevented on such clay soils unless a layer of stone, gravel or cinders is placed upon the sub-grade before laying the pavement or the slab made thicker over such soils.

In repairing such base failures it will usually be desirable to make such repairs with quick hardening concrete as described in the next part of this paper,

Repair of Portland Cement Pavements with Quick Hardening Concrete Made with Ordinary Portland Cement

Importance of Doing Good Work—Where it is desirable to open the patch to traffic as soon as possible after it is made, it is necessary that a concrete be used that will attain strength rapidly. Since the patches are usually small, and hence small amounts of concrete are wanted at intermittent periods, there is much greater danger of making a poor concrete patch than a new concrete slab in the original construction, unless great care is taken in doing the work. Inasmuch as it is desirable to make a stronger concrete and one that will attain strength quicker than in a new pavement, it is extremely important that we comply with every detail for making a good patch, from the preparation of the sub-grade to the finishing of the surface and protecting it against traffic until sufficiently strong. Unless the work is so done as to comply with all the requirements to make a perfect repair, it is far better that the repair be made with something else than concrete.

Cutting Away the Old Concrete—This can be done with picks, chisels, crowbars or jack hammer drill. The use of a paving breaker operated by a small portable air compressor is the most practical method if any quantity of work is to be done. All the broken and disintegrated concrete should be removed and the old slab cut back until solid, rigid concrete is reached which has on top a smooth and uniform surface. The top edge of the old concrete should be trimmed by hand (with the use of hammer and chisel) to a uniform and vertical edge for a depth of about 1 inch below the top surface. The remainder of the vertical edge of the concrete should be left as rough as possible. The base of the old concrete should be thoroughly brushed to loosen any spalled concrete.

Preparing the Sub-grade—The sub-grade ordinarily should be excavated to a greater depth than the original slab. At its junction with the old pavement the new slab shall be increased 4 in. to 6 in. deeper than the thickness of the old slab. Also, the new concrete should extend back under the edge of the old slab. The depth of the new concrete should depend upon the nature of the subsoil. The old concrete slab has failed for a reason. Quite frequently this reason will be found to be the soft clay subsoil. Therefore, the thinnest depth of the new slab should usually be 2 in. to 4 in. deeper than the old pavement. In very bad spongy clay soil, not only should the depth of the new slab be increased, but it is also an added factor of safety to tamp into the sub-grade a 3 in. to 4 in. layer of cinders, gravel or broken stone with an outlet to the side ditch. This will reduce capillary action in the clay and also help drain the surrounding sub-grade.

Composition and Proportion of Concrete—The concrete for the patches usually should be of a better grade than that used in good new concrete paving construction and it should be a concrete that will attain strength quickly so as to accommodate traffic with little delay. If large areas are to be replaced, economy would usually require a mix no richer than the standard mix concrete for paving. If only small areas are to be patched wherein the quantity of concrete involved is small, the added cost due to using a richer mix would not be so important an item. The time that traffic should be kept off the patch will determine the mix that should be used. The quick hardening concrete will depend for its early strength upon: (1) Richness of the mix; (2) freedom from excess water; (3) use of $CaCl_2$; (4) comparatively high atmospheric temperatures, and (5) coarse sand and properly graded sand and coarse aggregate. All of the above factors affect the time of hardening of the concrete mix. If we combine the most favorable features of all the above factors in one mix, we can make a concrete which assumes as much strength in two or three days as the ordinary concrete mix used in paving assumes in 21 days.

Traffic should be kept off the patch the number of days shown in Table 1. During cold weather, traffic should be kept off the new concrete a longer period than given in the table, as concrete gains strength slower at low temperature.

Cement should be tested at the laboratory and a report secured so as to know that it passes the required test. It is imperative that the cement is of good quality. Old cement that has lain around in a damp place until it has partly caked should not be used for this most important work. Some brands of cement attain greater strength than others at an early date. It is desirable to use such cement for repair purposes, if it can be conveniently secured.

TABLE I.—SHOWING THE MIX OR PROPORTIONS OF MATERIALS TO USE TO SECURE CONCRETE THAT CAN BE OPENED TO TRAFFIC AFTER ANY NUMBER OF DAYS.

1	2	3	4	5	6	7	8
	PROPORTIONS						
Days Patch Closed to Traffic	Bags of Cement	Cu. Ft. of Sand (0-¼″)	Cu. Ft. of Coarse Aggregate (½″-2½″)	Lbs. $CaCl_2$ or Qts. of "Standard Solution"	WATER Add enough to produce Slump given below	Bags of Cement per Cu. Yd. of Concrete	REMARKS
2	1	0.5	1.9	2	1″	11.8	This mixture to be used for small patches that are to be opened to traffic at the earliest date possible. Atmospheric temperature should average about 60° F.
3	1	0.6	2.1	2	1″	11.2	
5	1	1.0	2.7	2	1½″	8.4	
12	1	1.3	3.0	2	1½″	7.6	
15	1	2.0	3.0	2	1½″	6.8	
21	1	2.0	3.0	No $CaCl_2$	2½″	6.8	Standard Mix to be used where closing road to traffic is not an important item and where large areas are to be patched.

(5) This "Standard Solution" is made by dissolving commercial $CaCl_2$ in water at the rate of one (1) pound to enough water to produce one (1) quart solution. The pure $CaCl_2$ should never be added direct to the drum of the mixer. The "Standard Solution" should be added to the water just before it is put into the drum. See instructions under Calcium Chloride.

(6) Standard Slump Test. Fill with concrete a metal form shaped as a frustum of a cone. Form should be 12″ high with a 4″ top diameter and 8″ base diameter. Set the form on a level surface and as the concrete is put in the form, tamp lightly with a rod until a slight film of mortar appears on the surface. Then remove the form and immediately note the settlement or slump o t cohencrete whichi s a measure of its consistency.

Sand should be a comparatively coarse sand, 95 per cent of which passes ¼ inch mesh screen. It should be clean and free from silt or foreign material. The sand grains should be composed of hard gritty materials and be what is ordinarily known as a "sharp" sand. Sand from many local banks, which, though graded fairly well, contains a large percentage of soft particles, is not desirable.

Coarse aggregate should be crushed stone or gravel fairly well graded from ½ in. to 2½ in. in size. If the concrete is to be used to fill a crack or very small opening, the maximum size of aggregate will have to be reduced accordingly. It is imperative that this coarse aggregate be clean and free from pieces of wood, dirt, silt, shale or any soft particles. Rock of shale formation, although apparently hard and sound when first quarried, will cause failure of the concrete even though found in comparatively small quantities in the concrete.

Calcium chloride will be furnished in 100 lb. bags, which must be kept closed, as the exposure of the calcium chloride to the air will permit it to asborb moisture from the air and become liquid. It is quite important that the exact quantity of this material be used in each batch. An excess will weaken the concrete and insufficient calcium chloride will not hasten the itme of setting to prevent the pavement from being injured by traffic when opened after the number of days given in the table. The calcium chloride must not be added directly to the drum, as small undissolved particles remaining in the concrete will cause the concrete to disintegrate. The calcium chloride shall be added in the form of a "Standard Solution" made by thoroughly dissolving 1 lb. of commercial calcium chloride in enough water to produce one quart of solution. (This is at the rate of about 2½ quarts of the $CaCl_2$ to one (1) gallon fo water.) This "Standard solution" should be placed in a keg, jar or barrel and labeled "Standard Solution." Two quarts of the solution for each bag of cement should be added to the mixing water just before it is put into the drum.

Water must be pure and free from vegetable acids. The amount of water will have to vary so as to make the concrete of the proper consistency. In practice this will usually be found to vary from 2 to 5 gallons of water per sack of cement. However, when all the aggregates are thoroughly saturated with water after a rain it may be found that 2 quarts of "Standard Solution" will be sufficient water to make the required consistency. It should be remembered that excess water will reduce the strength of the concrete and delay the hardening process and not only permanently weaken the concrete, but also lengthen the time traffic will have to be kept off the patch. In order to secure the quick hardening effect, the concrete will have to be a sufficiently dry mix that it will show no more than the slump given in Table 1. (See description of slump test in footnote after Table 1.) Great emphasis should be placed on the importance of guarding against using too much water. The use of 3 or 4 pints more water than is necessary in a one-sack batch will reduce the strength of the concrete more than it can be increased by extending the time of mix. Hence, while it is necessary to use enough water to make a concrete plastic enough to be worked and properly finished, guard against using too much water.

Dampen the Sub-grade and Old Concrete—The subgrade and old concrete with which the new concrete comes in contact, should be wetted before the new concrete is placed. The sub-grade should be damp but not soft or sloppy. The edges of the old concrete should be saturated with water. It is very imperative, however, that no free water be present when the new concrete is applied, as the concrete that is to be opened to traffic soon after being placed depends largely for its quick strength upon having no excess water.

Mixing Concrete—Only machine mixed concrete should be used. It is almost impossible to get a maximum strength concrete, which is very imperative in repair work, if one depends on hand mixing. The usual time specified for mixing ordinary concrete in a mixer is one minute. However, tests show that the strength of a dry mix may be increased as much as 10 per cent by mixing one and one-half (1½) minutes, instead of one minute and the strength is slightly increased by extending the time to five (5) or ten (10) minutes. Hence, in repair work and where a small mixer is used, which will generally be less efficient than the big paving mixers, and where a dry mix is required for a maximum strength and quick hardening concrete, the time for mixing might well be placed at not less than two (2) minutes. This increased time of mixing will also make the finishing easier.

Placing and Finishing Concrete—Concrete should be shoveled in place and thoroughly tamped in layers not exceeding three (3) inches in depth. The secret of the early strength of the concrete will largely lie in a comparatively dry mix hammered in place. A 10-pound concrete tamper can be used for much of this work. A thin edged tamper having a face, say, 1″x6″ should be available for tamping for tamping in narrow openings and along the edge and underneath the old slab.

The concrete shall be finished with a straight edge and a wood float, to a regular and uniform surface to comply with the edge of the surface of the old pavement and the side forms. The straight edge should be used both transversely and longitudinally on the new concrete where the patch is not too long to do so. Where a full width of pavement is being replaced for a length greater than it is practical to use a straight edge, a templet cut to the proper crown of the road should be used. This templet can be used both as a cutting edge and tamper to produce a uniform surface. At either end of such a patch or straight edge should be laid longitudinally to insure a proper and uniform junction of the new concrete with the old pavement.

Completing Patch at End of Day—Since in making these patches we are dealing with a quick hardening concrete, it is desirable that a patch be entirely completed before leaving it for any length of time. Due to difficulty of shaping up the surface to conform with the old concrete slab with a dry mix, a patch should be entirely finished soon after the concrete is placed. It is necessary that a patch be entirely completed, including the finishing, at the end of a day's work.

The foreman should so plan his program that he can do other work for a fraction of a day if he has not time to entirely complete a patch before his workmen will quit work. Where large areas are being placed, a form board should be set vertically at the close of the day's work and the patch, including the finishing, completed to same as is done in the proper construction of a new pavement. No feather edge junction should be permitted. Owing to the fact that we are dealing with a quick hardening concrete when using calcium chloride, it is necessary to do the finishing promptly after the concrete is placed and tamped. After the concrete hardens to any extent it is almost impossible to make a smooth finish. It is important that the template and straight edge be used on finishing a partially completed patch so that the surface of the road will conform with the proper crown of the road and the old concrete surface.

Protecting New Concrete Patch While Curing—The newly laid concrete should be protected against any and all kinds of traffic the number of days specified in the Table on page 32. It is desirable that extremely heavy trucking be kept off the patch longer than this, particularly if the concrete is laid in cold weather as the concrete will harden slower in cold weather. The new concrete should be covered with six inches of earth or a layer of straw or sawdust, which should be kept dampened with water. Such covering should be kept on the new concrete about two-thirds of the length of the time traffic is required to stay off of same. The concrete should be protected against freezing the same length of time.

Cost of Concrete Repairs Made of the Quick Hardening Concrete Made of Ordinary Portland Cement

It will naturally cost much more to make concrete in small quantities as used in repair work than it will cost to make it in large quantities. Also the cost of cutting out the old concrete and making the excavation for the patch will be considerable. Furthermore, because of the variable conditions encountered with the different pavements being repaired, the costs will vary much more than in new work.

The best approximate cost data that we have been able to secure this past summer in making patches 9 inches deep of the quick hardening concrete made of ordinary Portland cement is as follows:

First job	Per sq. yd.
Cutting out old concrete and making excavations	$0.83
Materials delivered (aggregates, sand, cement, $CaCl_2$)	2.70
Labor (excluding making excavations)	1.44
Total cost per square yard	$4.97

This cost includes 10% added for equipment charge.
Second Job—$3.10 per square yard. No excavation.
Third Job—$3.10 per square yard. No excavation.

A new brand of cement known as Lumnite cement has recently been put on the American market. This cement attains as large a per cent of its full strength in 24 hours as ordinary Portland cement attains in 28 days. For this reason it is very suitable for making repairs where quick strength is required.

Blow-ups

Concrete slabs and brick pavements with grout filler occasionally rupture due to high compressive stresses caused by the combined expansive action of heat and moisture. Such ruptures are usualy called "blow-ups" and almost invariably occur on a very hot day in the spring of the year when the subgrade is still saturated. The wetting of the pavement from above by a summer shower which is followed by a hot sun produces a maximum condition of expansion which causes the blow-ups to take place.

It is a well-known fact that the better and denser grades of concrete are not only stronger to resist the forces due to expansion, but are also more resistant to absorption and are much less liable to be destroyed by temperature and moisture stresses.

Where such ruptures as described above occur, it is usually desirable to remove the injured concrete and replace it with new concrete as described under "Repairs of portland cement concrete pavements with quick hardening concrete made with ordinary portland cement."

Meaning of Terms Used in Design of Concrete Mixes

By ELWYN SEELYE

Modern practice in the proportioning of concrete involves the recognition of certain phenomena and the use of a number of technical terms to designate them.

The average engineer in reading articles on the subject is apt to become confused unless he understands the meaning of these terms.

Bulking—Bulking is the increase in volume of sand due its moisture content. If a cubic foot dry weighs 100 lbs. when it contains 6 per cent moisture by weight it will only weigh 85 lbs. per cubic foot.

Thus a 1:2:4 mix by volume will contain more sand when the pile is dry than when it is damp.

Cement Factor—Cement factor is the number of barrels of cement used to produce a cubic yard of concrete in place.

This cement factor is important for the contractor to know in making his estimate.

The cement factor can be used by the engineer to check the richness of a mix for concrete already in place provided he knows the number of barrels of cement used.

The cement factor can best be determined by measuring the actual volume of concrete in place produced by a standard batch.

Consistency—Consistency is the condition of workability, solidity or wetness of the concrete. It is measured by the slump or flow tests. Normal consistency is that condition of wetness which will have ½ in. to 1 in. slump. It is too dry for ordinary concrete construction, but is used to specify other consistencies. A consistency of 1.25 means using 25 per cent more water than that required for a normal consistency. An important fact is that, as the consistency becomes soft the strength decreases rapidly.

Fineness Modulus—Fineness modulus is a function of the sieve analysis of the aggregate. It is easily figured by dividing by 100 the sum of the percentages retained above each sieve in the A. S. T. M. standard sieves using Nos. 100, 50, 30, 16, 8, 4, ⅜, ¾, 1½ and 3 in. The fineness modulus bears certain definite relations to the amount of cement and consistency required to produce a given strength.

Flow Table Test—Flow table test is measure of the consistency. In brief, it differs from the slump test described below, in that it is a measure of the spread of the mass of concrete rather than the drop of same. The flow test is used in the laboratory because it is more accurate than the slump test but it is not used in the field.

Inundation—Inundation method of measuring sand is measuring the sand inundated or in water. Inundated sand overcomes both the bulking and variation of the moisture content in the sand. This provides an accurate method of measuring sand by volume.

Mix—The term mix is commonly used in the field instead of proportion. In discussions there are three terms used. Field mix, nominal mix and true mix.

A field mix is the relative quantities of materials as measured in the field or on the job.

Nominal mix is the mix obtained when the aggregate as measured in the field are dried and measured as in the laboratory.

True mix is the relation of cement to total aggregate where the aggregates are mixed and measured dry and rodded.

The following example will illustrate the difference: A field mix of 1 part of cement, 2 parts sand and 4 parts gravel may have nominal mix of 1 part of cement, 1½ parts of fine aggregate and 3⅞ parts of coarse aggregate and a true mix of 1 part cement to 4¾ parts aggregate.

Proportion—Proportions are the relative quantities of materials used in a concrete mixture. Proportions in a concrete mixture may be expressed in terms of volumes or weights.

Size of Aggregate—Size of aggregate generally means the size of the largest screen through which it is passed, but due to the greater refinement in modern methods of mix design the following more accurate rules have been adopted:

1. Not less than 15 per cent shall be retained between the sieve, which is considered the maximum size and the next smaller size.
2. Not more than 15 per cent of a coarse aggregate shall be finer than the sieve considered as the minimum size.

Slump Test—Slump test is used to determine the consistency of the concrete. It is made as follows: The newly mixed concrete or mortar shall be placed in three 4 in. layers in a truncated cone shaped metal mold 12 in. in diameter at the top and 8 in. in diameter at the base. Each layer shall be rodded as placed 30 times with a pointed ⅝-in. round steel rod. When the third layer has been rodded and struck off, the mold shall be lifted vertically at once. The drop below 12 in. is the slump; that is, if the pile is 8 in. high, the slump is 4 in.

Unit Weight—Unit weight is the weight of a unit volume, usually a cubic foot of aggregate or cement, unless otherwise stated it refers to the unit weight as measured under standard conditions, according to A. S. T. M. specifications.

Usual values for aggregates (dry and rodded) are:

	Lbs.
Sand	108
Gravel No. 4, 1½	107
Mixed sand and gravel aggregate	127

Water Cement Ratio—Water cement ratio W/C is the ratio of total volume of water to total volume of cement. The strength of concrete is affected more by this factor than by any other. The volume of water includes the moisture in the aggregate as well as that added at the mixer. The terms water ratio and slump are often confused. Suppose 1 cu. ft. of water is added to 1 bag (cu. ft.) of cement with no aggregate. The water ratio is 1 and the mixture is a thin paste with 12 in. slump. If aggregate is added to this mixture the slump will be decreased, depending upon the quantity of aggregate added, but the water ratio is still the same.

Yield—Yield is the ratio of the volume of concrete to the volume of aggregate contained in the mix.

Long Concrete Bridge Completed

Six-Mile Structure Joins Gulf Coast Cities

By ERNEST E. GARRISON

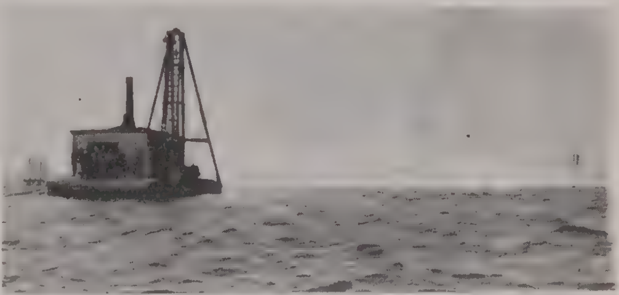
Concrete has provided one of the most important highway links ever constructed on the Florida west coast. The new Gandy bridge, crossing six miles of waste waters in Tampa Bay, Florida, and connecting the cities of St. Petersburg and Tampa, two of the fastest growing cities in the state, was opened late in 1924. A highway link that, for 20 years, has been dreamed about and talked about is now an actuality. Concrete and the automobile made its construction possible.

Seen from the air, the Gandy bridge is a wide ribbon of concrete stretching as far as the eye can see. The bridge proper is 13,000 ft. long, carried over the waters of the bay on reinforced concrete piling. More than 2400 piles were driven into the bed of the bay to solid rock to form the foundation for the broad concrete bridge deck. Piling, bridge deck, bridge railings—all units of the structure are built of concrete, strongly reinforced and poured in integral units by a floating mixing plant.

More than 25,000 cu. yds. of concrete, in which were used 170,000 sacks of cement, were required to build this important bridge structure. Thirty thousand tons of gravel and 15,000 tons of sand went into the mixture. More than 1,500,000 ft. of lumber was used in the building of forms.

For about two years large floating and stationary mixing plants were pouring the concrete.

Twenty years ago, George Gandy, a Philadelphia traction man, on a visit to St. Petersburg, saw the need of a highway link across Tampa Bay. "If somebody else doesn't build a bridge across the bay, I will," Mr. Gandy vowed. Years later he made preliminary surveys, and found a rock rib extending practically across the bay on a line with the route he had selected as the most logical for the bridge structure. Matters drifted on until the world war. Then after the war came the period of high material and labor markets, when it was thought inadvisable to begin construction. In 1922, however, the first steps in constructing the Gandy bridge were undertaken.



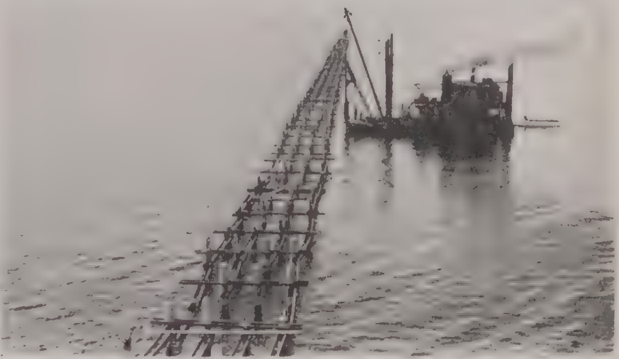
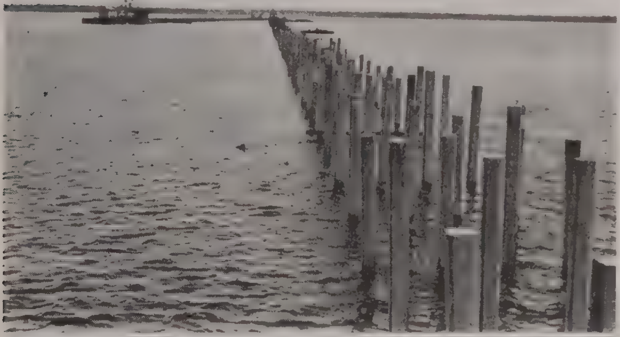


Fig. 3—After piling was driven, it was necessary to use dynamite in many cases to cut the foundation to the deck level. Hand tools, air tools and dynamite were employed. Here is shown a charge exploding several piles being capped at once
Fig. 4—Daily the Gandy bridge closed the long stretch across the bay. View taken near the drawbridge site looking west, showing piles ready for capping



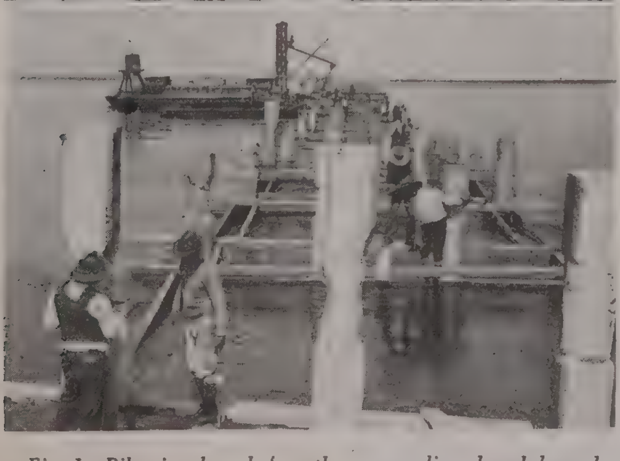


Fig. 1—Piles in place before they were aligned and braced
Fig. 2—Cutting of piles by hand

Borings indicated that there was sufficient sand at both mainland ends of the proposed bridge route to permit the construction of long sand causeways. The center rock rib was found to be covered by sand to a considerable depth in some instances, but it furnished an excellent foundation for the type of construction favored by engineers—reinforced concrete piling.

Three big dredges were started in the bay, and threw up a sand causeway on the western shore for some 12,000 ft. Previously, this part of the bridge route had been covered by water at mean low tide. These causeways were first thrown up as a narrow ribbon, and then the dredges worked back and forth until a sand fill about 400 ft. wide and 10 ft. above highwater had been built. At the eastern shore, a sand fill 4000 ft. long was thrown

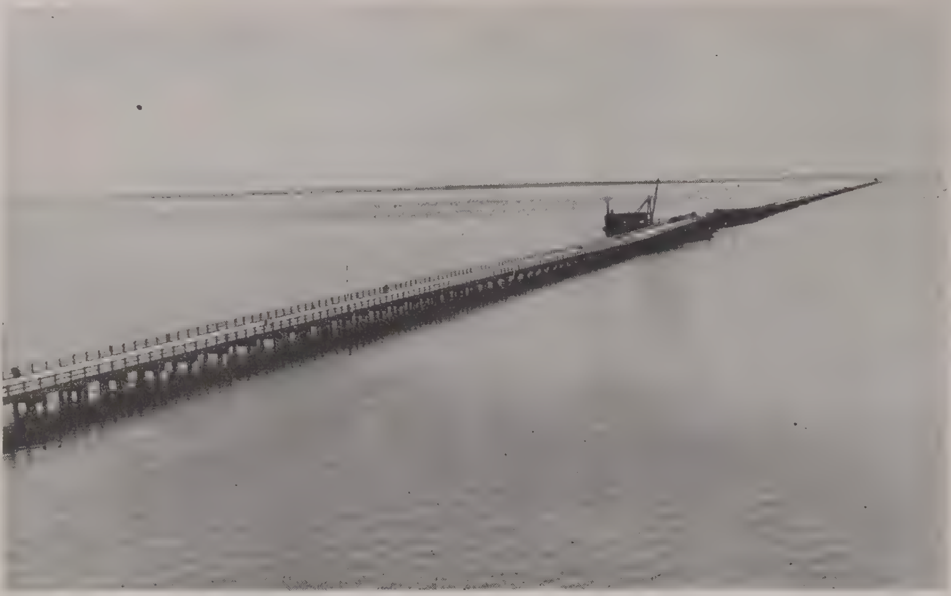
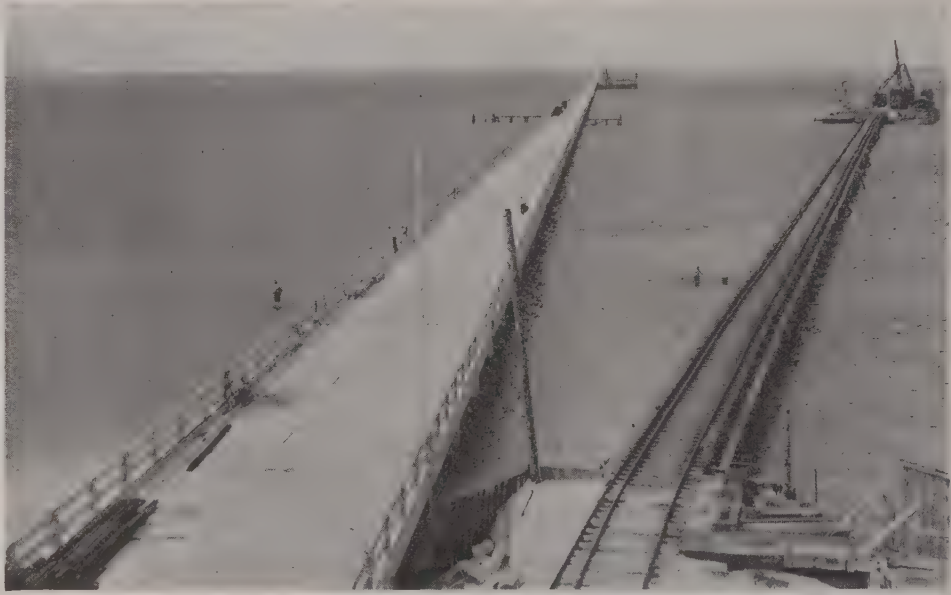


Fig. 5—Gandy bridge, St. Petersburg, Florida, looking toward western end from beyond eastern end of draw. This section of the bridge is 13,000 ft. long and 2,400 reinforced concrete piles were driven into the bed of the bay for the foundation of the bridge deck

Fig. 6—East end of the bridge looking west from deep water end of east causeway. Construction dock in right foreground



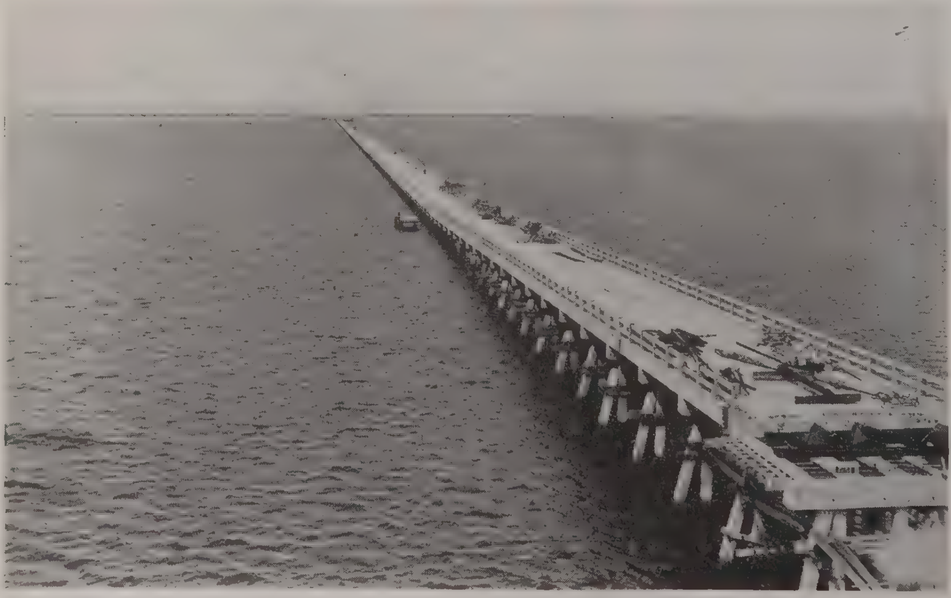
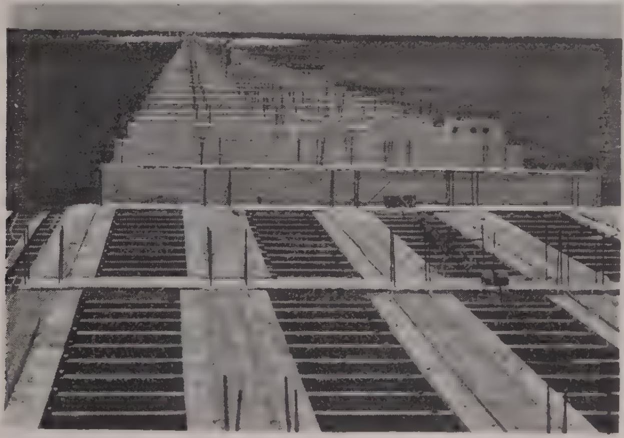
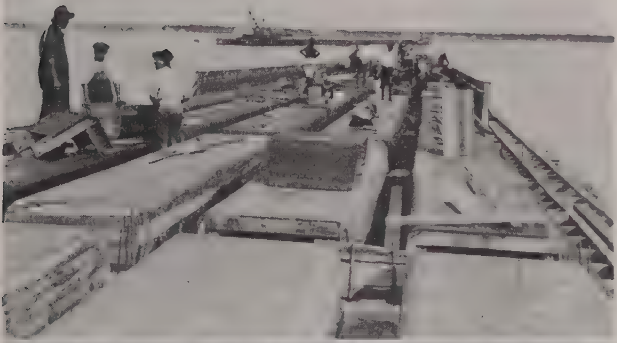


Fig. 7—West end of the Gandy bridge, looking toward St. Petersburg from drawbridge site





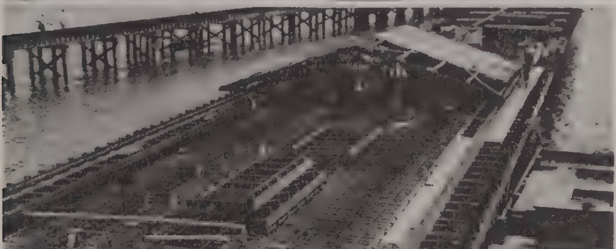
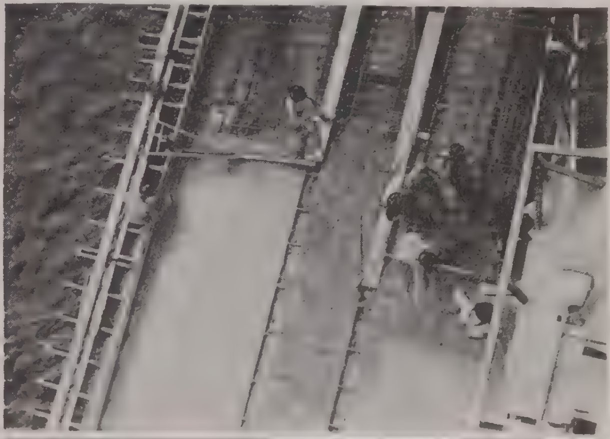


Fig. 8—Floating concrete mixer plant in operation near the drawbridge site. Foreground-foundation forms in place at drawbridge
Fig. 9—Concrete caps showing first assembly of floors of deck forms in foreground
Fig. 10—Deck forms in place almost ready for the reinforcing steel gang
Fig. 11—Forms and reinforcing steel in place for the bridge deck

up. These causeways were then bulkheaded with concrete buttments, and the construction of the actual bridge structure began.

While the sand fills were being thrown up, a stationary concrete plant of the eastern shore was occupied in building the reinforced concrete piles on which the bridge was to rest. Twenty-four hundred piles, varying in length from 20 to 60 ft., were poured at this plant before operations ceased. From time to time tests of the mixture were made to determine the strength of the piles, and an average compression strength of 385 tons per pile was achieved.

Then came the problem of setting the piles into the bed of the bay. A quadruple pile driver, equipped with water jets and steam hammers, handling four piles at an operation, was started from the eastern shore of the bay in July, 1923. These piles were placed 5 ft. on centers and 24 ft. between bents. Very nearly a year was required to place the piling, align them and cut them off to the proper height. Some of the piling was driven through the sand strata to bed rock. Others were placed in drill holes and sunk in solid rock to a minimum depth of five feet.



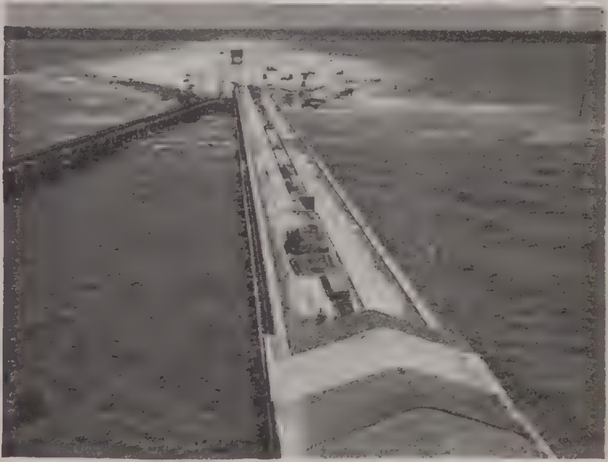
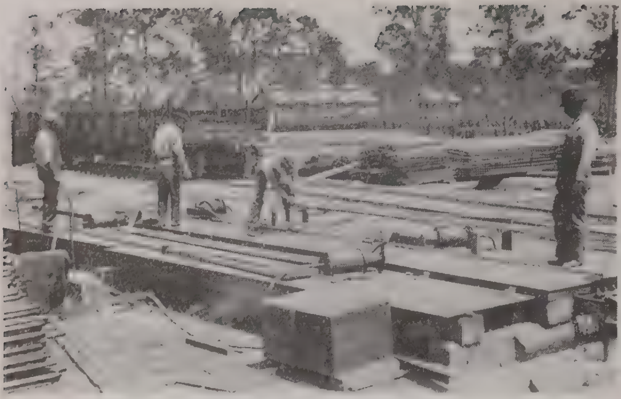
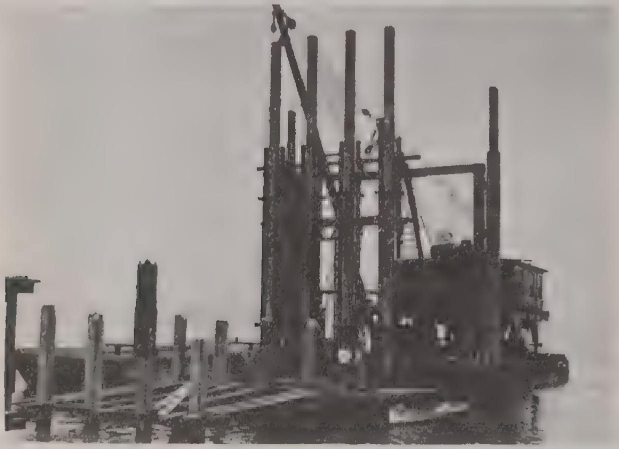


Fig. 12—Pouring concrete of the deck span
Fig. 13—Section of completed bridge deck. The traveling shelter shown in foreground was later dispensed with and no shelter used

Because of the character of the mixture, the task of cutting off some 2400 piles to the proper bridge deck level was a long and tedious job. Hand tools, air tools and dynamite were used in the process.

After the piles were cut, a floating mixing plant was employed to pour the mixture into the cap forms set on top of the piling, which held the piling and bents in a rigid unit. After this concrete had time to harden, the





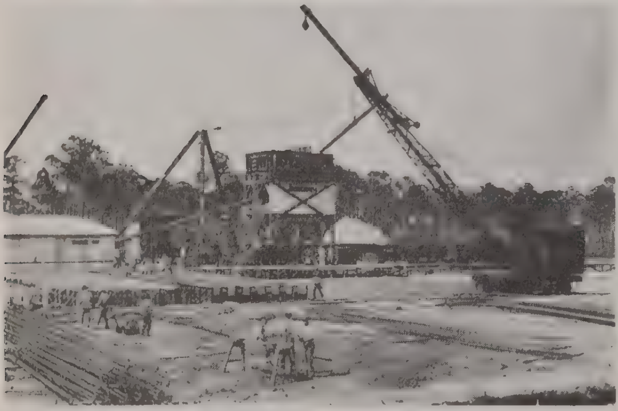


Fig. 14—Shaping reinforcing rods at Gandy bridge. Boiler plate tables and air cylinders from freight cars formed the equipment employed to shape reinforcing steel built into piles, bridge deck and railings

Fig. 15—Quadruple pile driver, which handled four concrete piles 5 ft. between centers. Steam hammers and water jets were used to drive the piling into the sand bed to solid rock, or to place the piling in drilled holes in rock bed. The piles varied in length from 20 to 60 ft.

Fig. 16—Pile casting plant at Gandy bridge. Left foreground—assembled reinforcing steel for piles

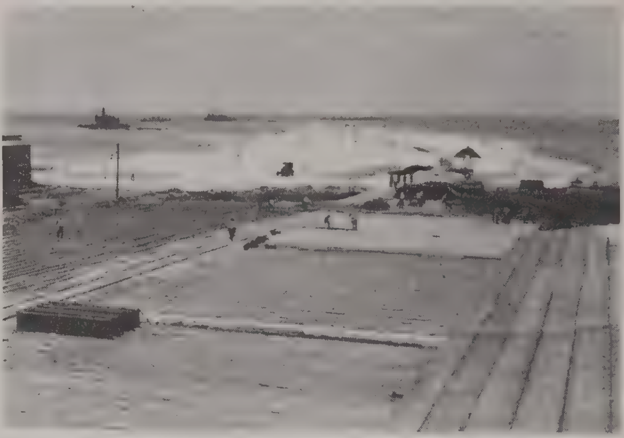
bridge deck was poured and the railings cast. The reinforcing steel was so designed that all parts of the structure are effectively tied together. Bending of the steel and shaping the reinforcing material was accomplished through the use of a boiler plate table on which air brake cylinders from freight cars had been bolted.

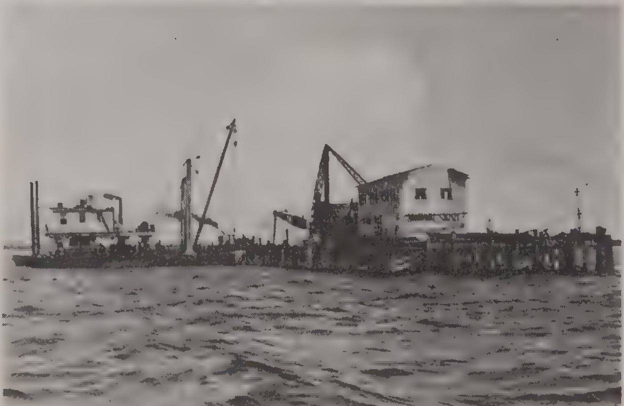
In September, 1924, the last concrete was poured, with the exception of the toll house walls, which were later completed.

The bridge deck, some 13,000 ft. long, is carried over a stretch of the bay which has a mean depth of 10 ft. except at the draw channel which has been dredged to 23 ft. A 75-ft. bascule steel draw spans the channel. The roadway is elevated 7 ft. at the draw. Eight reinforced concrete cylinders 5 ft. in diameter, topped by and tied together by heavy concrete slabs, form the base for the draw structure.

Throughout construction, the weather was a constant menace to construction. The winter of 1923 brought several severe tropical storms, one of which capsized the large floating concrete plant and several barges. This plant was immediately rebuilt and commenced operations again in April. Temperature, of course, caused no construction delays, the accidents to operating equipment being responsible for the tieups experienced.

The area abutting the bridge ends, before the construction of the sand causeways began, was mild and undeveloped. Only very poor sand trails led to the shores





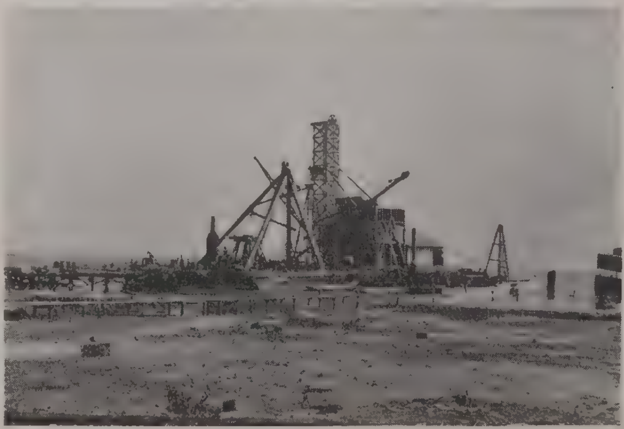


Fig. 17—Pile casting yard in the foreground. East causeway and dredges in the background

Fig. 18—Temporary construction pier 1100 ft. long

Fig. 19—The big floating concrete plant which capsized in a storm in March, 1924

of the bay. It was necessary for the engineers to construct a two-mile railway to connect with the main lines of the Atlantic Coast Line railway, and to clear off and drain land for the construction plant. A deep water pier 1,000 ft. long, on which was mounted a heavy-capacity crane, also had to be built before construction was commenced.

The new bridge is built to accommodate four motor cars abreast, and is electrically lighted for its entire length by powerful General Electric units. Two toll houses, one at each end of the bridge causeways, are provided, and traffic lanes so arranged that three lines in one direction and one in another may be handled simultaneously, preventing delays at the toll houses. Automatic scales weigh and classify motor trucks.

Many engineers from all sections of the country have watched the progress of the bridge with interest, and particular interest has been noted in the building and operation of the quadruple pile driver, which successfully handled the driving of the 2400 piles without difficulty.

Proposed Reinforced Concrete Construction to Relieve Traffic Congestion

By **CHARLES HURST**
Chief Engineer, Trinity Portland Cement Co.

The problem of space in modern cities is each year pressing heavier on urban communities, and a careful review of the various solutions that have been offered would indicate that no more promising line of advance can be found than a bold adoption of the possibilities of reinforced concrete construction.

The accompanying outline drawing illustrates the writer's proposal for economizing space and relieving the traffic of downtown streets. It will be seen that the scheme consists of throwing a reinforced concrete structure across the street between two buildings and utilizing the space enclosed by the bridge structure for offices. A walk for pedestrians is carried immediately beneath the bridges and at this level an additional line of stores could be accommodated. Thus the space for foot passengers could be increased or alternatively the sidewalks of the street reduced in width to give more space for automobile traffic. The elevated sidewalk would be accessible both from the bridge and from the main buildings, and by elevators from the street below. Traffic regulation of the street would be greatly accelerated, as the necessity for pedestrians crossing the street would be eliminated.

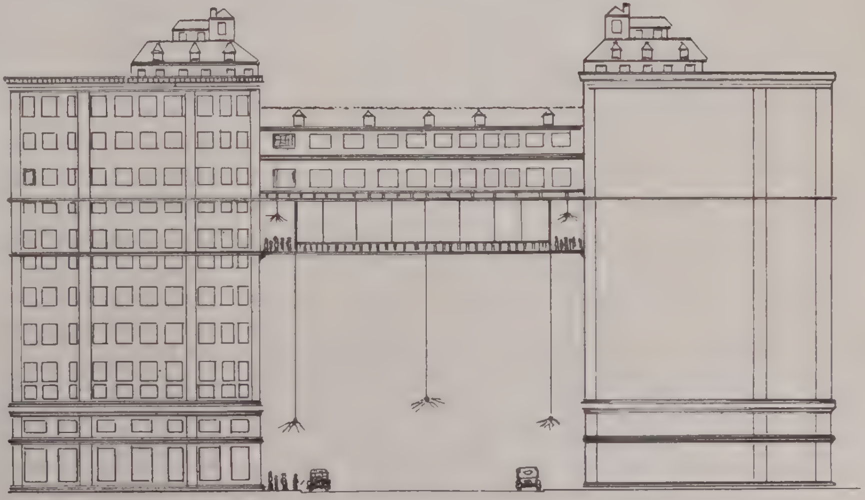
This construction presents no great technical difficulties. The sides of the bridge being of monolithic reinforced concrete, form in effect deep girders of immense strength, and the reduction in strength due to the window openings is practically insignificant since they occur in the region of the neutral axis of the deep bridge beams. The floor of the bridge would form part of the tension member of the bridge beam, and suitable reinforcement would take care of the stresses in this part. The top flange of the beam would not be of excessive dimensions to keep the unit area stresses low, by reason of the great depth of beam. The biggest problem of the technical design would be to provide for the heavy shearing forces at the bridge ends, but calculations demonstrate that there is no insuperable difficulty here.

The heavy loads on the fronts of the buildings would necessitate careful design, and adequate piers and foundations would be necessary to meet the loads imposed by the bridge and the elevated sidewalks. We may imagine the two office buildings shown in the accompanying sketch to be higher by half the length of the bridge, and this additional height brought over at right angles to meet the corresponding addition on the opposite building.

To carry out this scheme would of course require considerable co-operation between the interests of the opposing sites. The bridges should alternate with spaces not too great to carry the sidewalk bridges running parallel with the street. The height of the intervening buildings would be subject to no limitations since they would not necessarily be required to carry the elevated sidewalks, these being in the form of concrete bridges carried from the upper concrete cross bridges. In other words, cooperation to the extent of building on alternative sites on each side of the street is called for, the municipalities contributing to the cost of the elevated sidewalks. This scheme offers great scope for bold design and magnificent elevations.

Modern reinforced concrete construction and the high qualities and strength of present day finely-ground cement and its alumina compounds place within the command of the engineer and architect possibilities of construction which greatly facilitate the solution of city problems that would have been almost unsurmountable a generation ago.

Fig. 1—Proposed scheme for economizing space and relieving traffic on congested streets by arranging opposite buildings with connecting bridges which also provide additional office space and support longitudinal elevated sidewalks



Effect of Type of Coarse Aggregate on Quality of Concrete

By STANTON WALKER
Associate Engineer, Structural Materials Research Laboratory, Lewis Institute, Chicago

The characteristics of the aggregate have less effect on the quality of concrete than is commonly supposed. Good concrete can be produced from aggregates which are often considered inferior, if grading of aggregate, mix, consistency, etc., are taken into account properly. This important fact has been obscured in many investigations due to the general disregard of differences in grading of aggregate and consistency of concrete when experimental studies of different types of aggregate were made.

Tests carried out by a number of different investigators have shown that if the consistency of the concrete and grading of the aggregate are kept the same, concrete of approximately the same strength and resistance to wear is obtained for a wide range in types of aggregates. These results are in accord with the water-ratio theory of concrete mixtures; that the strength of concrete depends on the ratio of volume of mixing water to volume of cement, so long as the concrete is workable and the aggregates are made up of clean and durable particles.

Compressive strength and wear tests of concrete on about 150 samples of coarse aggregates collected from widely scattered sources are summarized in Bulletin 10 of the Structural Materials Research Laboratory, "Wear Tests of Concrete," by Duff A. Abrams. The principal results of these tests are given in Table 1. The aggregates include pebbles and crushed limestone, granite, trap, sandstone, blast furnace slag, tufa, fire brick, cinders, etc. In these tests the same grading was maintained for the different aggregates by separating into three sizes and recombining in definite proportions; the same sand and cement, and concrete of the same plasticity was used with each. The specimens were tested at 3 months.

TABLE I—WEAR AND COMPRESSION TESTS OF CONCRETE MADE FROM MISCELLANEOUS COARSE AGGREGATES†

Wear tests of 8 by 8 by 5-in. concrete blocks made in Talbot-Jones rattler.
Compression tests of 6 by 12-in. cylinders.
Mix 1:4 by volume of mixed aggregate; approximately same as 1:2:3 mix.
Relative consistency, 1.10; about the same as should be used in the construction of concrete roads to be finished by hand.
Hand-mixed concrete; one specimen to a batch.
Cement: a mixture of five brands of portland cement purchased in Chicago.
Sand from Elgin, Ill., graded 0 to No. 4, used as fine aggregate in all tests.
Each coarse aggregate was screened and recombined to the following grading: No. 4 to ⅜-in., 25%; ⅜ to ¾-in., 50%; ¾ to 1½-in., 25% by volume.
For each aggregate sample, the value for wear was the average of 10 tests and for strength, 5 tests, made on 5 different days.
Specimens stored in damp condition 14 days, then in air until tested at age of 3 months.

	Coarse aggregate				Concrete tests* (3 months)	
Kind	Number of samples tested	Unit weight lb. per cu. ft.	Apparent specific gravity	Absorption at 3 hr. per cent by weight	Compressive strength lb. per sq. in.	Depth of wear inches
Pebbles	24	102	2.56	1.17	4330	0.51
Crushed limestone	26	91	2.59	1.14	4560	0.44
Crushed granite	12	92	2.59	0.32	4350	0.34
Crushed trap	6	95	2.85	0.12	4210	0.40
Crushed sandstone	7	86	2.34	3.94	4470	0.45
Crushed slag	13	88	2.34	2.20	4240	0.48
Crushed flint	2	83	2.43	......	4850	0.46
Crushed marble	1	96	2.69	0.39	4620	0.42
Crushed lava rock	1	90	2.62	2.50	5350	0.40
Crushed tufa	1	47	1.27	27.50	1960	0.66
Crushed fire brick	1	70	1.92	4.55	5390	0.43
Cement clinker	2	88	2.22	8.20	5160	0.37
Boiler cinders	1	40	1.51	8.70	3000	0.85

*Strength tsets were also made at ages of 7 and 28 days, and 1 year on many of the aggregates.

†Same as Table 1, Bulletin 10, Structural Materials Research Lab., "Wear Tests of Concrete," by D. A. Abrams.

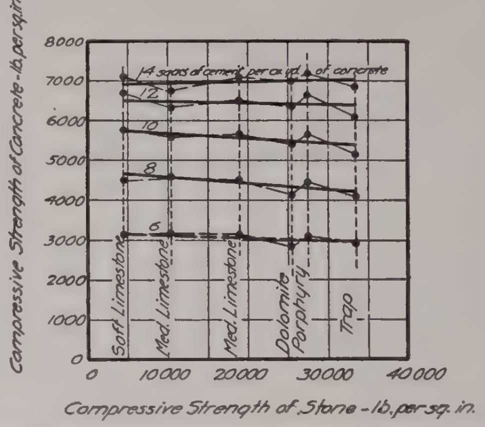


Fig. 1. Relation between Compressive Strengths of Concrete and Aggregate:
Compression tests of 6 by 12 in. concrete cylinders and of 2 by 4 in. stone cylinders.
Each value for the concrete strengths is the average of 5 tests made on different days.
Concrete tested at 28 days
Same fine aggregate used in all specimens; each coarse aggregate separated into two sizes and recombined to same grading

The table shows that approximately the same average strengths and depths of wear were obtained from pebbles, limestone, granite, trap, sandstone, blast furnace slag, flint and marble. The range in average strength for these different types of aggregates was from 4210 to 4850 lb. per. sq. in.; the depth of wear ranged from 0.34 to 0.48 in.

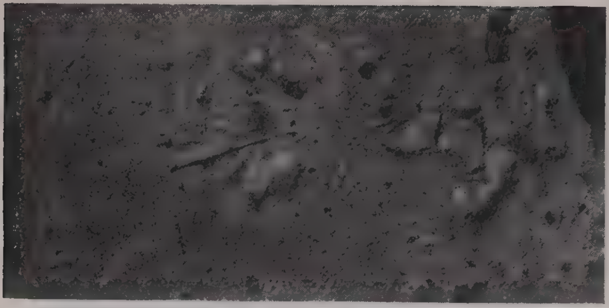
Friable aggregates, such as tufa and cinders, gave concrete strengths lower than the average—1960 and 3000 lb. per sq. in. respectively. The resistance to wear was also lower, the tufa giving a depth of 0.66 and the cinders 0.85 in.

Lava rock, fire brick and cement clinker gave somewhat higher strengths than the average (5300 lb per sq. in.); the resistance to wear was about the same as for the ordinary aggregates.

Samples of the same type of aggregate collected from widely separated sources gave fairly uniform results as illustrated by the 24 lots of pebbles, for which the minimum strength was 3690 lb. per sq. in. and the maximum 4940 lb., a maximum variation of 15 per cent from the average. The extreme values of wear for the pebbles were 0.74 in. and 0.44 in. A similar degree of uniformity was found for the other materials.

Prof. F. E. Giesecke of the University of Texas, published data showing the same general results (*Engineering News-Record*, June 29, 1922).

Tests at 28 days and 3 months are reported. Fig. 1, from Prof. Giesecke's article, summarizes the 28-day tests. The abcissa give the compressive strength of the stone and the ordinates, the strength of concrete made from the same stone. The crushed stone aggregates had compressive strengths ranging from 4400 to 33,600 lb. per sq. in., but the same grading of aggregate, consistency of concrete, and quantity of cement, approximately the same concrete



After nine years of heavy traffic on Myrtle Boulevard, in Sioux City, Iowa, the impression of a leaf, made when the concrete was placed, is still clearly visible

strengths were obtained. Aggregate having a maximum size of ½ in. was used. This size is smaller than ordinarily used for concrete; Prof. Giesecke points out that this may have minimized the effect of type of aggregates on concrete strength. However, the results are in entire agreement with Abrams' tests, in which aggregates graded up to 1½ in. were used.

Saucer-shape Reinforced Concrete Floor Supports Stage

Use of Slag as Aggregate Permits Light Slab Construction

By PAUL CALFAS

Courtesy of Concrete and Constructional Engineering

An interesting reinforced concrete floor has recently been built below the mechanism of a new revolving stage at the Grand Theatre, Lyons, England, and has provided space for a cafe beneath the stage.

The floor is circular, about 65 ft. in diameter. In the center the spindle on which the stage above revolves passes through the floor, and the new floor is supported at the center by a circular reinforced concrete wall, 11 ft. 6 in. in diameter, surrounding the spindle and keeping it out of the sight of those using the cafe. At its outer edge the new floor rests on a circular reinforced concrete beam which also serves as a traveling track for the rolling mechanism of the stage.

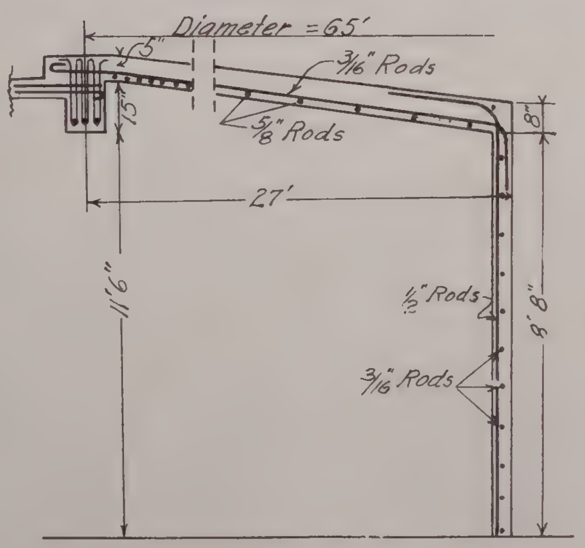
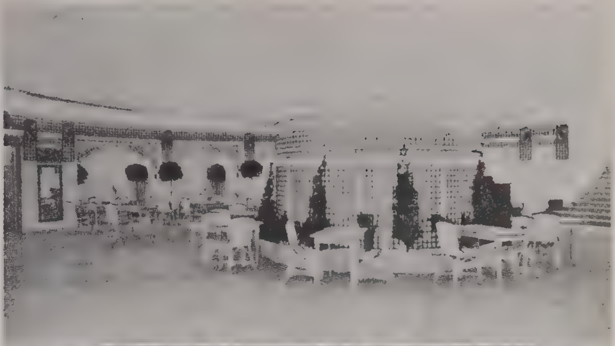


Fig. 1—Half-section of saucer-shape reinforced concrete floor beneath a theater



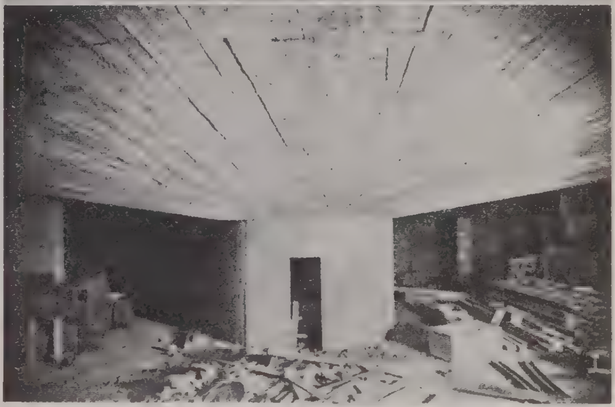


Fig. 2—The cafe completed
Fig. 3—During construction

In designing the floor the general theory of flexible rotating surfaces was used, and the floor built of a minimum thickness. In order to reduce the weight, and consequently the stresses on the reinforcing bars, slag was used as the aggregate in the proportion of 1 part quick-hardening cement to 8 parts slag. With the use of this mixture the maximum thickness of the floor was kept down to 8 in., while it was estimated that if a gravel concrete had been used it would have been necessary to make it 15 in. thick. The maximum thickness of 8 in. is at the center, decreasing to 4¾ in. at the circumference. The total weight of reinforcement in the floor is only 8 tons.

The method of construction without girders enabled a considerable economy in formwork to be effected, and further to use as little timber as possible the floor was concreted in sections: after one section had set the formwork was rotated about the center wall and placed ready for concreting the next section without lowering it from the level of the floor. Two timber frames were used, each extending over one-twelfth of the surface, and as the quick-hardening cement set in two days, it was thus possible to concrete practically continuously.

The slag used for aggregate was free from the coke and sulphur pyrites, and was sieved to two sizes, one between ¼ in. and 9/16 in. and the other between 3/32 in. and ¼ in.; these two sizes were mixed in the proportion of two parts of the smaller to one part of the larger.

It is estimated that the method of design and erection, and the use of slag for the aggregate, effected savings of 50% on the concrete, 55% on the weight of steel and 40% in the time of erection.

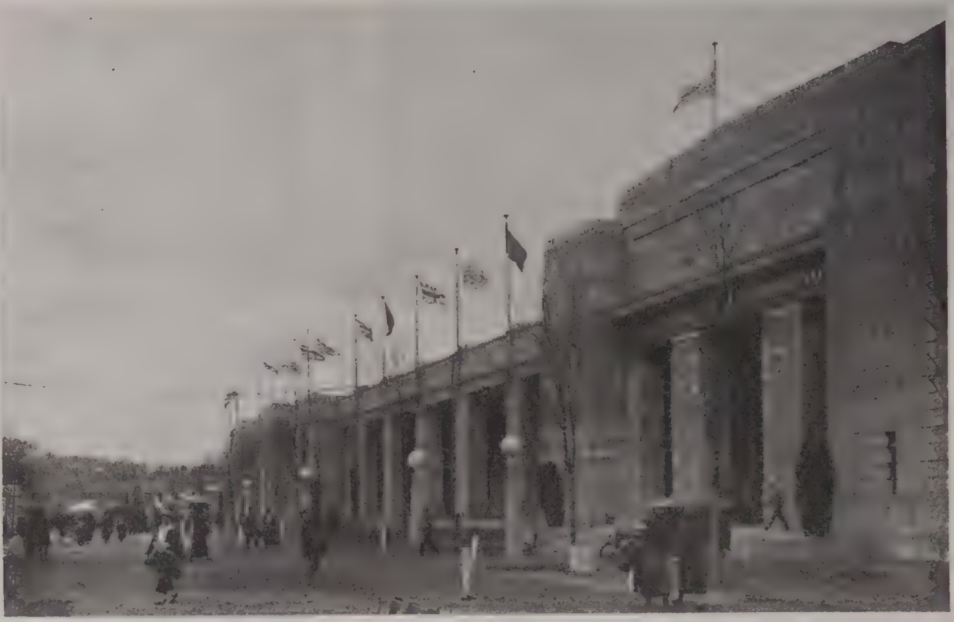


Fig. 1—Palace of Engineering, British Empire Exhibition. World's largest reinforced concrete building covering an area of over 13 acres

British Progress with Concrete in 1924

By A. C. BLACKALL
London, England

In the British constructional world the rapid progress of concrete was well maintained during 1924.

The vast collection of huge and imposing buildings completed in the early months of the year at Wembley for the British Empire Exhibition constituted what is probably concrete's greatest triumph in Great Britain up to the present time. Thousands of tons of concrete were used in the construction of these buildings, allowing great economy of design and construction. The largest—the Palace of Engineering—is claimed to be the biggest ferro-concrete structure in existence. It covers an area of 596-000 sq. ft. A point which these exhibition buildings served to emphasize is that concrete, if properly used, is in itself capable of producing the best architectural effects without the aid of extraneous facing materials.

Bridge and Dock Construction

In no branch of civil engineering has concrete proved of greater service than in dock and quay construction and bridge work, and many very extensive schemes involving such structures were in progress in the United Kingdom during 1924. In the great extensions to the docks and dockside buildings of the port of Liverpool, still to be completed, an immense amount of concrete construction, both plain and reinforced, was embodied last year. The extensions to the Avonmouth docks at the port of Bristol and the construction of further new docks at the port of Glasgow are other noteworthy examples of large-scale operations in which concrete played an all-important part. At the Glasgow docks are three reinforced bridges to carry a new road over the dock railway extension. Two of the bridges are of four spans and one of two spans, and all are designed to carry the exceptionally heavy traffic to and from the docks.

Waterworks

Another class of work in which concrete continued to make excellent progress last year was in connection with public water supply schemes. A striking instance of its application in this direction has been furnished by the completion towards the close of the year of a new reservoir for the Leicester Corporation at Evington. This reservoir, which has a capacity of 5,000,000 gallons, is divided into two distinct parts, so that one section can be utilized while the other is being cleaned or repaired. The reservoir is covered with a concrete roof, the average thickness of the slabs of which is only 5 in.

Interesting structures carried out in the same category of work were two reinforced water towers, built as part of the Ely Rural District Waterworks extensions. Each of these towers has a capacity of 100,000 gallons.

Concrete Houses

In numerous housing schemes throughout the country, due to the scarcity of bricks and bricklayers, concrete construction in various forms has been adopted with much success at far less cost than brickwork. A recent suburban contract for a housing scheme of over 100 houses was decided upon late last year at from $100 to $175 lower cost than brick. And this in the vicinity of brickfields, obviating haulage costs for the bricks. Further, it is not necessary to cover externally or rough-cast the whole of the walled surfaces with cement plaster (which is really a thin layer of concrete), as is the English custom with brick houses of the same type.

In the erection of huge commercial and industrial premises, which since the war have been continually built in London and the other large British cities, full use has been made of concrete. A building of particular interest in relation to the use of this versatile material is the new Fortune Theatre in London, which was completed last year. This is London's first all-concrete theater. The principal facades of this edifice are faced with

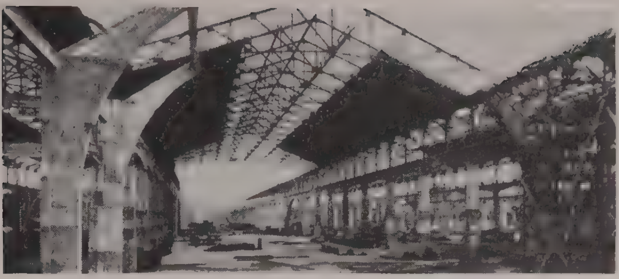


Fig. 2—Interior view of Palace of Engineering during construction

concrete made with Derbyshire pearl spar and a well-known patent white cement, the wall surfaces having been brush-hammered after the striking of the shuttering.

One building of some interest in concrete work is the Singapore New General Post Office. A fine plaster model of this structure was exhibited in the Malayan Pavilion of the Empire Exhibition. The building, which is estimated to cost $5,000,000, will stand on two acres and will, when completed, be one of the finest buildings in the Orient. It will comprise the post office, the Singapore Club and numerous business offices. The principal facade is 446 ft. long, with a maximum width of 204 ft., the total height being 138 ft. In order to distribute the load so as not to exceed one ton per foot super, the foundations of the building comprise a rectangular reinforced concrete raft. Architectural features are receiving special attention, and external facings are of a special synthetic stone, made from granite chippings and white cement.

The improvement of Great Britain's transport facilities by the construction of great arterial roads continued satisfactorily during 1924, involving engineering achievements in which concrete figured prominently. Bridges, retaining walls, embankments, culverts, road foundations, curbing and foundry walling and fencing were among the many uses to which it was put in this connection.

Rehearing in Cement Case Suggested

(Washington Correspondence)

The U. S. Supreme Court will not make known until the October term whether or not it will grant a petition filed by the Government for rehearing its case against the Maple Flooring Manufacturers Association and the Cement Manufacturers Protective Association, in which the court held May 30 last that trade associations may carry on numerous forms of activity for the intelligent conduct of business without trespassing against the Sherman anti-trust law.

The court's decisions were hailed by trade associations generally as vindication of the legality of their functions and the Government's petition for rehearing has occasioned considerable surprise in view of the statement made by Attorney General Sargent following the court's action overruling the Government's contentions that, fortunately for all, the issues raised with respect to the legality of trade association work had been disposed of.

It is only on rare occasions that the Supreme Court permits rehearing. In the present instance, its decisions have been regarded, however, as a reversal of the attitude assumed by the court in its decision of the American Column & Lumber case in 1921. Changes in the personnel of the court have been pointed out as accounting for this change, although Justice Stone, in writing the opinions in the recent cases, sought to show that there was no overruling of the previous decisions, and that it was the abuse of the associations' statistical services, rather than the system itself, that had been condemned by the court in the earlier opinions.

Associate Justices Sutherland, Butler and Stone, who voted with the majority in the recent cases, were not on the bench in 1921. In the Linseed Oil case, decided June 4, 1923, there were no dissenting opinions and the court appeared to be unanimous in condemning the practices engaged in by the Armstrong Bureau of Related Industries. The most recent decisions indicate, however, that this appearance of unanimity was deceptive. Justices who in fact dissent from majority opinions of the court frequently refrain, for one reason or another, from filing dissenting opinions and are, therefore, listed with the majority. The court may have stood and probably did stand five to four in the Linseed Oil case, with the subsequent seating of former Attorney General Stone as a member of the supreme bench shifting the majority.

Straub and Bo Cinder Products Interests Combine

The Straub and Bo rival interests in processes for the manufacture of concrete building units have ceased to be rivals and are now combined. This is disclosed in the announcement of the newly formed Cinder Concrete Corporation, organized under New York State Laws, which has obtained from Crozier-Straub, Inc., and Cinder Products Corporation the sole and exclusive right to grant licenses under the Straub Patent and the Bo Patent for the manufacture and sale of cinder concrete products.

The whole situation with respect to the development of cinder concrete building units and the patent processes was reviewed in CONCRETE in June, 1924.

There are now in operation in various parts of the country 66 plants manufacturing cinder building units, and the industry is rapidly expanding. Some of the existing plants are licensed under United States Letters Patent No. 1,212,840 granted to Francis J. Straub and others under United States Letters Patent No. 1,466,083 granted to Sigurd Bo.

One of the purposes for the organization of the new corporation is to make practicable the licensing of new plants under either or both of these well known patents.

All of the officers and men associated with both Crozier-Straub, Inc. and Cinder Products Corp. will retain their relationship with the industry in the new corporation and there will be made possible united effort for the development of the cinder concrete industry and the betterment of existing processes and methods of manufacture and the extension of the use and distribution of cinder blocks, brick and tile.

Mr. Straub and Mr. Bo as president and vice-president will be in general charge of the business of the new company; G. Edgar Allen will be manager of the company and in charge of its principal office in New York. Raymond Wilson will be in charge of the field work. Einar Christensen will be manager of the engineering service department of the new company and will devote a large part of his energies to scientific research and educational work. Both Mr. Bo and Mr. Straub started as bricklayers and still carry their union cards. The new corporation is officered as follows: President, Francis J. Straub; 1st vice-president, Sigurd Bo; 2nd vice-president, Joseph A. Beck; treasurer, E. B. Cadwell; assistant treasurer, George W. Farron; secretary, Charles L. Pierce.

The main office of the Cinder Concrete Corporation will be at No. 120 West 42nd Street, New York City, N. Y., and branch offices in Union Trust Building, Rochester, N. Y., and in Park Building, Pittsburgh, Pa.

The Design of Cement Concrete Pavements

(Continued from page 28)

of shrinking upon drying out. There seems to be some ground for believing also the subgrade might take up water from the concrete with a resulting local vertical expansion of the subgrade material which exerts upward force in spots, again with a resulting cracking of the concrete. This action is especially prevalent on subgrades having bad characteristics such as previously pointed out and, as stated, the remedy seems to be the provision of a sand layer. Unless immediate measures are taken to keep the concrete moist the moisture will evaporate and shrinkage will occur. Since shinkage must result in the dragging of the concrete over the subgrade and consequently in the setting up of tensile stresses, it will be seen how necessary it is to keep the concrete moist to prevent this action. Tensile stresses must not be permitted until the concrete has gained sufficient strength to develop resistance to tension. The concrete is therefore kept moist, preferably for a period of at least several weeks. It is then allowed to dry out and immediately it begins to shrink and draw itself over the subgrade. This action necessarily results in the production of tension in the concrete and when frequent expansion joints are not provided transverse cracks are unavoidable at this period. The higher the resistance of the concrete to tension the further apart are these transverse cracks and it is therefore important to delay the shrinkage of the concrete as long as possible in order that high tensile strength might be attained. In the meantime, as the concrete has been hardening, the temperature of the air has been changing almost every hour and that part of the pavement in contact with the subgrade necessarily remains at a more uniform temperature than the top surface. The top surface, therefore, has been expanding and contracting owing to thermal effects, while the bottom surface has been remaining relatively stationary. This necessarily results in the bending of the slab and to the setting up of bending stresses due to the dead load of the slab and to the local effects of the expansion and contraction within the concrete. It might also be the case that a period of high temperature might occur resulting in an expansion of the concrete and the production of high compressive stress. Finally the pavement is opened to traffic and immediately there are additional stresses of flexure due to the bending action of heavy wheel loads applied sometimes with static and sometimes with dynamic effect. Traffic also tends to abrade the immediate surface and it is therefore necessary that it have high resistance to abrasion.

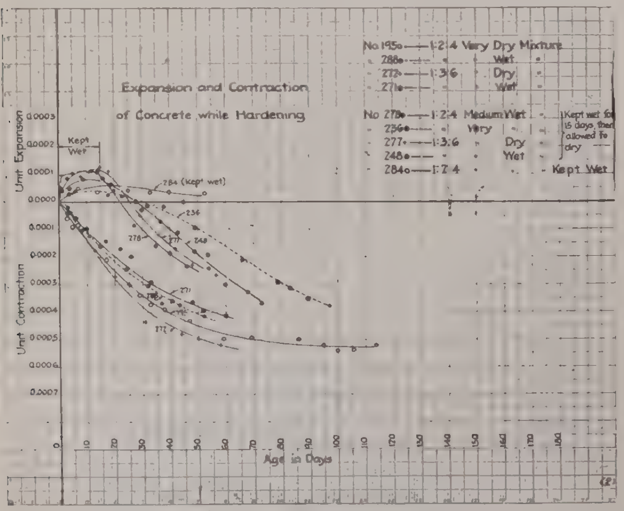


Fig. 2

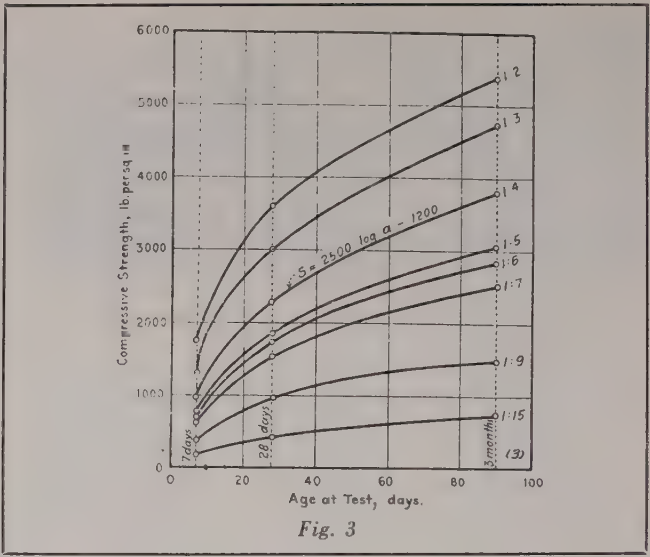


Fig. 3

We are now in a position to set down the various properties of concrete which seem to be important for consideration in the design of a concrete pavement. They are

1. Expansion and contraction due to changes in moisture.
2. Expansion and contraction due to temperature changes.
3. Tensile resistance of concrete.
4. Resistance to bending.
5. Compressive strength.
6. Resistance to repeated stress.
7. Resistance to abrasion.

Expansion and Contraction of Concrete Due to Moisture Condition

A number of experimenters have studied the action of moisture on the changes in length of concrete, but perhaps more work has been done on neat cements and mortars than on concrete of the proportions used in highway construction. This subject was studied at the Bureau of Public Roads in 1911,[3] and recently has been studied at of Michigan.

Curves typical of those obtained at the Bureau of Public Roads are given in Fig. 2. It will be observed that as long as concrete is kept moist it remains expanded, but that as soon as it is subjected to drying out conditions it begins to shrink and in this its properties resemble those of timber. The maximum percentage of expansion obtained in the Bureau of Public Roads Tests amounted to 0.0001 in. per inch of length and upon complete drying out the shrinkage was approximately 0.0005 in. to Purdue University and I understand also at the University 0.0006 in. The amount of shrinkage depends to a considerable extent on the characteristics of the cement used and also in the degree of drying to which the specimen has been subjected. The more complete the drying, the greater the percentage of shrinkage. It is not to be expected that road concrete will shrink to the same extent as laboratory concrete because the underside of the slab is invariably at least damp, whereas a laboratory specimen may become quite dry. When a specimen which has been dry is again subjected to moisture conditions it expands, but the rate of expansion is very low, as seen from the curves in Fig. 2. The presence of reinforcing steel

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[3] Dept. of Agriculture Bulletin No. 532, "The Expansion and Contraction of Concrete and Concrete Roads," by A. T. Goldbeck and F. H. Jackson.

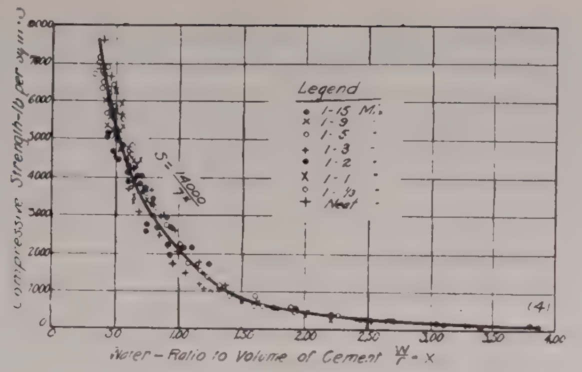


Fig. 4

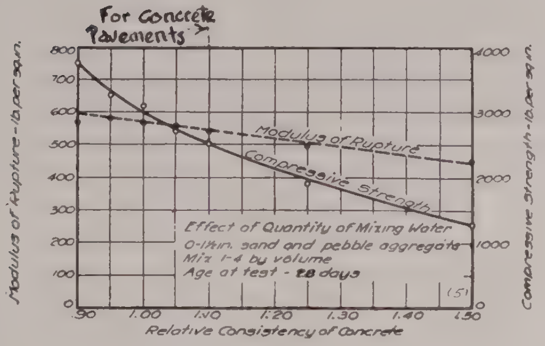


Fig. 5

reduces the shrinkage of concrete due to the evaporation of moisture, as also illustrated in Fig. 2.

Temperature Expansion of Concrete

We have been accustomed to accept a figure for the coefficient of expansion of concrete of approximately .0000055. Recent experiments, however, conducted at Purdue University under the direction of W. K. Hatt seem to show that the coefficient of expansion ranges from .0000040 to .0000065, the latter figure applying at a temperature of 150° F. and the former at approximately 60 F°. The exact figure, no doubt, will depend upon a number of factors, including the characteristics of the cement and aggregates, and the age of the concrete and perhaps at this time no more definite statement can be made of the coefficient of expansion of concrete subject to temperature change. If we accept our customary figure of .0000055, a length of concrete of 100 ft. shrinks .0000055 × 100 × 100° equals .055 ft. of .66 in. for a change in temperature of 100° F. It necessarily follows that changes in length of a concrete pavement, produced either by temperature or moisture changes, must be accompanied by the production of direct tension or compression within the concrete. These stresses will be treated in detail elsewhere.

Compressive Strength of Concrete

Numerous experiments have been made on concrete cylinders to determine the effect of the different variables which affect the compressive strength. Perhaps the greatest amount of work along this line has been done under the direction of D. A. Abrams of the Lewis Institute, Chicago. In Fig. 3 there is reproduced a set of curves taken from the Lewis Institute results. The curves in this figure show the rate of growth of compressive strength of the different mixtures of concrete and in Fig. 4, also reproduced from Professor Abrams results, is shown the relation between the compressive strength of concrete and the so-called "water cement ratio." This curve illustrates very strikingly that the strength of concrete depends principally upon the ratio of the volume of water to the volume of cement used in the mixture, irrespective of the proportions of that mixture so long as the mixture is "workable." Apparently 3000 lbs. concrete such as is desirable for pavement purposes requires a water cement ratio of about .8 or about six gallons per bag of cement.

It is obviously impossible to go into the details of the various effects upon the strength of concrete of the variables to which it might be subjected. The strengths shown in the accompanying curves were obtained under conditions ideal for curing. It is desirable that the concrete used be so proportioned and cured that it will attain 3000 lbs. at 28 days when cured under road conditions and such variables as temperature of atmosphere during hardening and duration of curing, both affect the resulting strength irrespective of the consistency, proportions, condition of moisture of the specimen upon testing and method of testing. Generally speaking, compressive strength of road concrete is not particularly important expect in so far as it indicates the general quality of the concrete.

Modulus of Rupture

Perhaps the most important quality which road concrete must possess is that of high resistance to cross-bending. When a crack forms in a concrete pavement this results either from direct tension or from cross-bending. In Fig. 5 are shown results of cross-binding tests expressed in terms of modulus of rupture. The term modulus of rupture is applied to the stress which exists at the most remote fibre of a beam upon failure, the stress being calculated by the ordinary formula for flexure:

$$S = \frac{Mc}{I}$$

Where M = maximum bending moment.
c = distance from neutral axis to most remote fibre.
I = moment of inertia of cross-section.

Judging from the curves herein shown, no direct relation can be stated between the compressive strength of concrete and the modulus of rupture. In view of the fact that high bending stresses are produced by heavy loads, pavement concrete must possess a high value for modulus of rupture, preferably not under 600 lbs. per square inch at 28 days. As in the case of compression, the cross-breaking strength of concrete is affected by many variables. Perhaps one of the most significant effects, however, is that of the condition of moisture of the specimen at the time of testing. Recent experiments at Purdue University have shown that a beam which is comparatively saturated has a strength only 75 to 85% of a beam which is air dried and that the strength may be varied

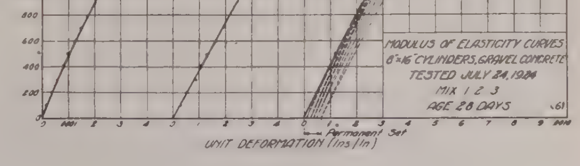


Fig. 6

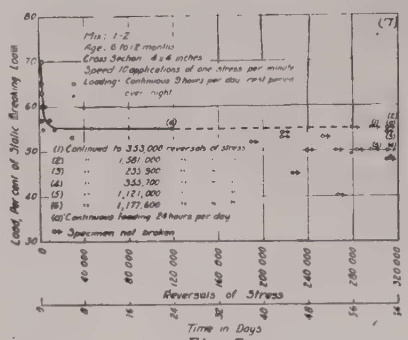


Fig. 7

both above and below the dry strength, depending upon the depth of saturation of the concrete.

Modulus of Elasticity

By modulus of elasticity we mean the ratio of unit stress to unit deformation and this value directly indicates the relative stiffness of the concrete under the application of load. A typical modulus of elasticity curve is shown in Fig. 6. On this curve is shown the amount of deformation per inch of length for the different stresses applied. On the curve is likewise shown the permanent set which takes place in concrete after stress has been applied and again released. Concrete is not perfectly elastic but yields permanently under load and under a long application of load it has been shown by the investigations in the Bureau of Public Roads, and elsewhere, that this yielding is apt to continue. The modulus of elasticity of concrete in tension for practical purposes may be considered as identical with its value in compression. The value of the modulus of elasticity of road concrete varies greatly, depending on conditions and ranges between approximately 2,500,000 to 5,000,000 or even higher. In a general way high compressive strength is apt to be accompanied by a high value for modulus of elasticity.

Fatigue of Concrete

During the passage of heavy vehicles a concrete pavement is subjected to stress, then the stress is released or often reversed from compression to tension. On a heavily traveled road this happens several thousand times during a single day. It is thus evident that it is important to know something of the effect of fatigue on the behavior of concrete. A number of experiments have been performed along this line, notably by Purdue University, by the Illinois Department of Public Works and also by the University of Maryland.

As indicated in Fig. 7, the Purdue tests seem to show that when a beam is not stressed beyond 54% of the modulus of rupture of the concrete it can be subjected to reversals of stress of this magnitude indefinitely. On the other hand, when the stress produced is in excess of this amount comparatively few reversals can be applied before failure takes place. This applies to dry concrete alone. When the concrete is saturated the results recently reported by Dr. Hatt are very significant. He reports as follows:

> The saturated beams showed 89% of the static strength of the dry beams.
>
> Beam No. 162 failed at 200 reversals under a load equal to 55% of the once applied load; duration of test, one-third hour.
>
> Beam No. 161 failed at 8,400 reversals at 50% load; duration one-half day.
>
> Beam No. 165 at 17,200 reversals of 50%; duration 1¼ days.
>
> Beam No. 164 at 71,700 reversals of 40%; duration five days.
>
> These tests are being continued. It would appear that something less than 55% of the static strength of dry concrete should be the working strength of the saturated concrete of road slabs.

Tests such as cited above indicate the value for unit stress beyond which it would not be safe to load a concrete pavement if cracking under loads is to be prevented. Apparently if the concrete is to be kept in a rather dry condition the unit stress should not exceed 50% of the modulus of rupture. In a saturated condition, even 40% is none too low a unit stress to use. It is perhaps generally the case in most concrete roads that the concrete does not remain saturated for any great length of time; there are exceptions, however.

Tensile Strength of Concrete

There are times when a concrete roadway is subjected to direct tension. It is important, therefore, that something of the tensile resistance of concrete be considered in connection with concrete road design. A few scattered tests have been made on concrete in tension and in general these results might be summarized by the statement that, roughly, concrete in direct tension has approximately 1/12 of its strength in direct compression. On this basis the tensile strength of concrete which has a compressive strength at 28 days of 3000 pounds would be approximately as follows:

At 7 days—100 lbs.
At 15 days—194 lbs.
At 28 days—250 lbs.
At 3 mos.—400 lbs.

It is quite likely that there might be considerable variation from these figures depending upon the large number of variables to which the concrete might ordinarily be subjected.

(To be concluded)

Concrete Built Around Steel Stack

How to save a steel stack, 180 ft. high, from toppling over and at the same time keep a power station in con-

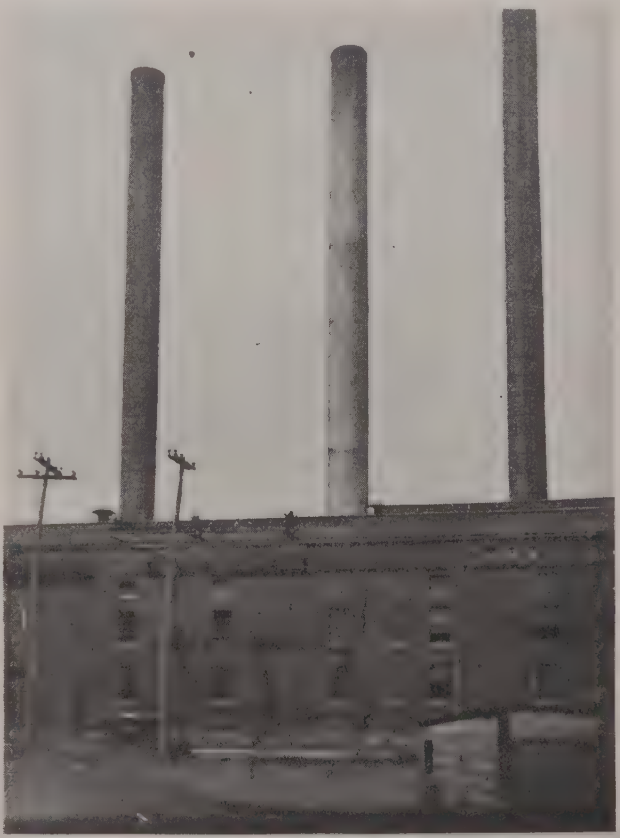


Fig. 1—The center stack shows completed structure made by building a reinforced Guncrete jacket around corroded steel stack

stant operation was the difficult problem that confronted officials of the Public Service Company, at Waukegan, Ill. To meet this emergency it was finally decided to construct a Guncrete stack, using a process developed by the Cement-Gun Construction Co., Chicago. It was stipulated in the contract that the building operations should not make it necessary at any time to shut down this central portion of the plant.

A new reinforcing structure was planned, of steel rods so arranged as to take all the stresses; in other words, the new stack was not to depend at all on the old stack for its support. The new stack was securely anchored to the old foundation by means of the existing foundation bolts; these were extended by means of sleeve nuts and 1½-in. rods and a wire mesh fabric was added to this structure of rods. It was so designed as to distribute more evenly the stresses and to carry the green concrete until set.

A layer of asbestos board was wrapped around the hot steel stack, inside of the reinforcing structure. This served as a compressible sheathing and prevented the contraction and expansion stresses of the steel stack from being communicated directly to the outer stack.

Guncrete was then shot in place. A coating was applied, 8 in. thick at the bottom and tapered gradually to 4½ in. at the top. This mixture was 3½ parts of No. 2 torpedo sand and one part of portland cement, shot into place with cement-guns, at a pressure of 50 lbs. per sq. in., using a 14 by 12 single stage compressor driven by a 50 h.p. motor. As much of the work was done in cold weather and at a time of high winds, canvas protection was needed most of the time.

An Interesting Dock Construction in Copenhagen

By E. LEE HEIDENREICH

From a paper by G. Lorenz, M. Ing. F. in Ingeniren. Abstracted

Among the many different dock and quay constructions described by G. Lorenz in his interesting paper in *Ingeniren* of Dec. 20, 1924, the dock at Teglholmen takes high rank for wave breaking purpose and of a design, which is unique and just covers the case.

The depth of the water around Teglholmen ranges from 23 to 26 ft., and the clay was exceptionally hard. No piling could be driven, as the lime rock reached up to the base of the dock, and to overcome the pressure from the steep bank the wall was inclined towards the clay bank about one-half of its height, as shown in Fig. 1, and reinforced concrete anchors were placed on 13 ft. centers to secure the wall, as an additional measure to that of effecting a center of gravity at an appreciable distance from the front.

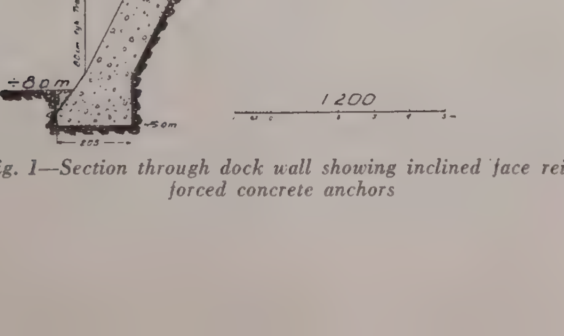


Fig. 1—Section through dock wall showing inclined face reinforced concrete anchors

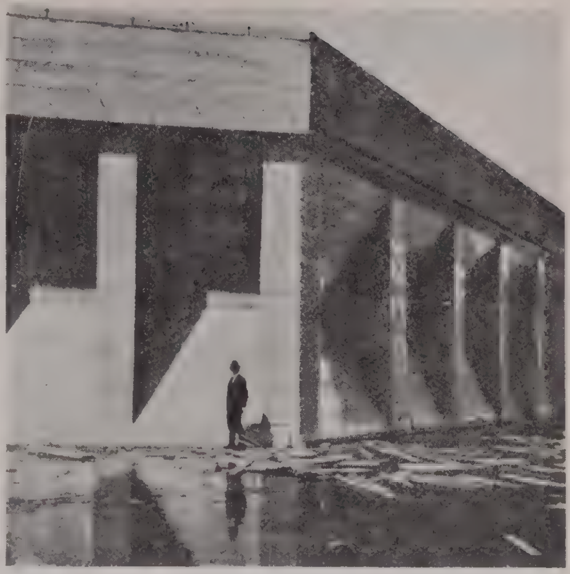


Fig. 2—View showing an angle in the structure

The wall is 3.9 ft. at the bottom and 3.3 ft. at the top, and the mix was 1:3:5.

The anchors are 10 ft. by 14 ft. with eight 1¼ in. steel rods, fastened in the dock front and in the anchor plates.

The Effect of Fine Grinding Cement

About 10 years ago the bureau began an investigation to determine the effect of fine grinding of cement on the strength of concrete. Since the beginning of the work other investigators have shown this effect for short periods of time, usually one year. It is felt that the bureau's tests are of particular interest, as they extend over a 10-year period, and show the effect of fine grinding on the strength of concrete at definite intervals of time during this period.

For the investigation five commercial brands of cement, as received direct from the manufacturers and representative of their marketable product, were used. Each cement as it was received was thoroughly mixed and divided into two lots. One lot was used as received for making concrete, while the other was ground in a ball mill for one and one-half hours before use.

Concrete cylinders 8 by 16 inches were made from both lots of cement, Potomac River sand and gravel being used as the aggregate. The materials were proportioned either 1:2:4 or 1:3:6 by volume. After remaining in the molds for 24 hours the specimens were stored in moist air for 28 days. After the 28 days' curing the specimens were placed out of doors exposed to Washington weather conditions until broken. Compressive tests were made at the 7-day, 28-day, 6-month, 1, 2, 3, 5, and 10-year periods. The extreme variation in fineness in the two lots of any one cement was 20.1% on the standard No. 200 cement sieve.

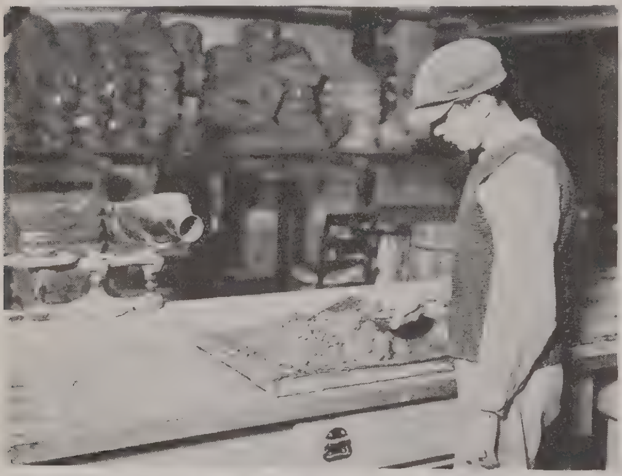
From the results of these tests the following conclusions may be drawn: No retrogression is shown in the compressive strength of the concretes at the end of the 10-year period. In general, the fiitness of the cement increased the strength of the concrete. All cements do not give the same increase in strength with the same increase in fineness. The effect of fineness of cement on the strength of concrete diminishes with age. The 1:2:4 mixes show better increases of strength with the same increase in fineness than do the 1:3:6 mixes.—Bureau of Standards, *Technical News Bulletin.*

Joe Prusa—Artisan

Expert Cement and Concrete Tester

These pictures show "Joe" Prusa, who rules the "underworld" of the Structural Materials Research Laboratory, Lewis Institute, Chicago; i. e., the basement of the laboratory with its labyrinth of dark passage ways and light workrooms where under Joe's supervision approximately 35,000 mortar and concrete test specimens are prepared annually. As his work is exclusively for research purposes, it has to be done very carefully and carries with it considerable responsibility. However, Joe is equal to it.

For investigations which require unusual accuracy the specimens are made by Joe personally. In a recent investigation it was necessary that one operation make the entire series which consisted of some 5300 specimens. Joe did it in less than two months.



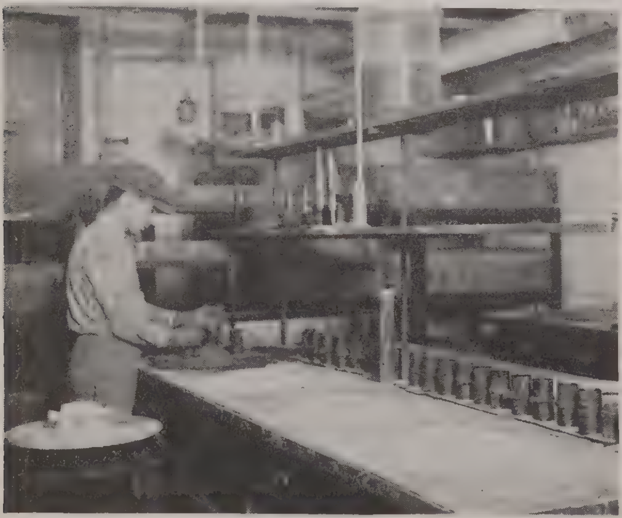
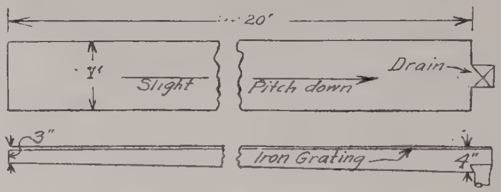


Fig. 1—Mixing samples of concrete in pan
Fig. 2—Making 21x4 cylinders of 1:3 mortar

Joe came to the laboratory in March, 1917, when he was only seventeen. He soon worked up from the ranks until now he has complete charge of the work of making concrete and mortar test pieces and has from four to six men working under his direct supervision. His ambition does not leave him when he is away from the laboratory for during his spare time, he makes ornamental concrete and lays concrete floors. His latest form of "amusement" is the construction of a concrete garage. Wearing overalls and rubber gloves seems to agree with him for he is noted for his cheerful disposition. "Do you know," he said, "that if all the specimens that have been made since I started to work here were used as mile posts on a concrete road, they would reach from here to the moon."

An Improved Washrack

One of the disadvantages of the common automobile washrack, with the floor pitched to a center drain, is that so much mud and dirt are flushed into the drain pipe that both it and the sand traps below require frequent cleaning out. Drain pipe stoppage from this cause is not at all unusual.



Sketch showing inclined drain

Several Motoramp garages have adopted the sloping-trough-drain illustrated in the accompanying sketch.

The advantage of this arrangement is that the heavy dirt will settle in the trough and not go down the overflow drain pipe. This type of washrack drain is adaptable for a single or multiple car wash stand. It is recommended that the pitch of the bottom of the trough be not more than 1 in. in 20 ft.—or just sufficient to cause a flow toward the drain pipe. If the washrack is longer than 20 ft., it would be advisable to provide two drain pipes. The drain trough should be fitted with an iron grating.

The trough is wide enough to enable a shovel to be run along the bottom and pick up the mud which accumulates. If the washrack is in active use this should be done two or three times a day. It saves the much greater time and expense of cleaning out pipe lines and sand traps.

Silicate of Soda in Patching Concrete

Cement floors when once laid ought not to be cut into; but sometimes, wear or the removal or installation of machinery makes a patch essential. That silicate of soda can be used to insure a good bond between old and new concrete is pointed out by the Philadelphia Quartz Co., in *P's and Q's.* First the hole should be chipped out clean and of such a shape that the new piece will lock into the old concrete, that is, the hole should be somewhat undercut. The fresh surface should then be painted with silicate. Pure portland cement may then be dusted over the surface and worked in with a broom or stiff brush. The fresh concrete can then be applied in the usual manner.

For resurfacing a considerable area of floor, the concrete should be roughed with a pick, then all loose particles should be removed and the floor wet thoroughly with water over night. Immediately before the new surface is applied, the old one should be washed with a mixture containing one quart of silicate, diluted with 14 quarts of water and containing 10 lbs. of cement which is put into the diluted silicate solution immediately before applying it to the floor. This mixture should be brushed in well and followed at once with the surface layer.

Field Tests of Bridge

By HARLAN D. MILLER
Bridge Engineer

Courtesy *California Highways*, the official publication of the California Highway Commission.

Careful tests have been made during the last year and a half of the strength of concrete used in the construction of state highway bridges in various sections of California. These tests are of considerable interest because they show the strength of concrete obtained under actual working conditions, using variable aggregates and different brands of cement.

In all, about 800 samples of concrete were taken during the construction of fifty bridges. These samples were secured on the job as the concrete was poured from the mixers; precautions being taken in each case to see that the samples were typical of all of the concrete to the run, and that, in every respect, they represented average conditions. About on-half of these samples were tested at the end of ten days and the remainder after twenty-eight days of curing.

Pasteboard cartons, in the shape of cylinders six inches in diameter and twelve inches long, are used in casting samples, which are kept on the job under the same conditions as the concrete in the structure until of the desired age for breaking. They are then shipped to the state testing laboratory at Sacramento. The ultimate strength of the concrete in compression at the particular age is thus determined.

Tests Fair Representation

In making the concrete covered by the tests completed to date, there were used seven different brands of cement and aggregates from many sections of the state and of considerable variableness; twenty resident engineers participated in the supervision of the work. Taking these factors into consideration, it may be assumed that the tests fairly represent actual field concrete as it is now being produced in California state highway bridges.

The bridge department is making a very earnest effort to secure uniformity of results in its concrete, rather than exceptionally high strength. With this in view, the resident engineers are drilled in the theory of proportioning of aggregates, careful measurement of water content, bulking of sand, etc. Aggregates are proportioned according to the Abram's theory to produce the greatest workability with the least amount of water.

The average slump of the concrete used in the fifty bridges, built during the last year and a half, was about 2¼ inches. This includes concrete for columns, beams, girders, slabs, arches, railings, posts, and piles.

On the accompanying chart is plotted the results of field tests of concrete going into seven bridges on the state highway trunk line between Sacramento and Stockton (X-Sac-4-B). This chart is typical of our bridge concrete.

Tests Show High Strength Concrete

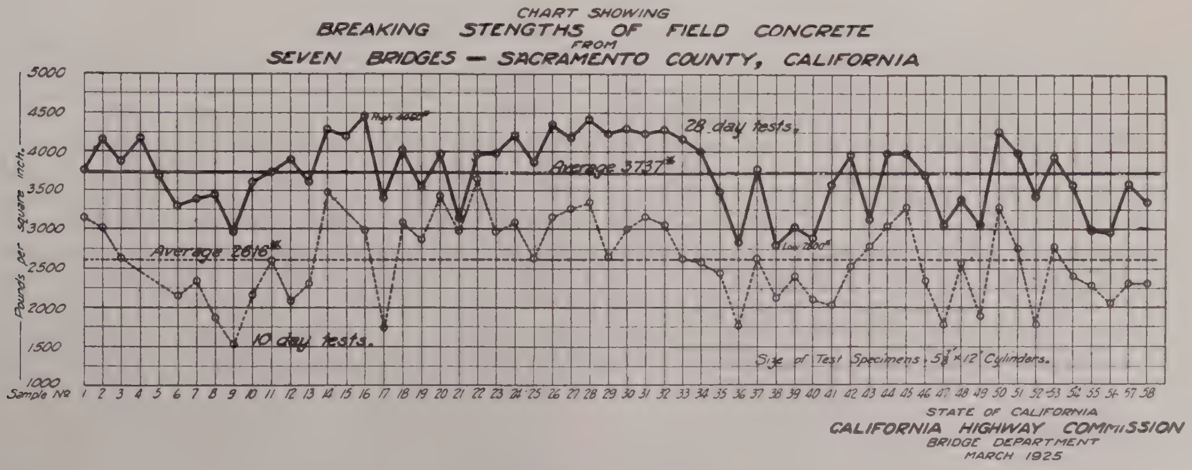
If the average strength of concrete produced in the bridges covered by this chart were used as a basis for the allowable unit stresses in design, as recommended by the Joint Committee on Standard Specifications, the allowable stress would be 1500 lbs. per square inch. If the lowest break, namely 2800 lbs. per square inch, were used, the allowable unit stress for design in compression would be 1120 lbs. This compares favorably with the allowable unit stress of 650 lbs. per square inch used in the design and approved in the committee's specifications.

The bridges covered in the chart were built under the supervision of A. J. Meehan, resident engineer, with D. C. Willett, assistant bridge engineer, assisting in the proportioning of aggregates. The tests were made by the testing laboratory under the supervision of C. L. McKesson, research engineer for the construction department, and E. T. Maddocks, testing engineer.

The contractors on this project were T. H. and M. C. Polk of Chico.

New Fellowship in Highway Engineering

The National Slag Association, with headquarters at Cleveland, Ohio, has recently established a fellowship in Highway Engineering to provide for the investigation under the direction of the Division of Highway Engineering and Highway Transport of the University of Michigan of an approved subject relative to the utilization of blast furnace slag in the construction and maintenance of roads and pavements. The National Slag Association Fellow will make extensive investigations in the laboratory relative to the properties of slag in the field pertaining to results secured by the utilization of slag in the construction of different kinds of roads and pavements.



Field test of bridge concrete

Autogenous Healing of Concrete

By DUFF A. ABRAMS

Professor in charge of Structural Materials Research Laboratory, Lewis Institute, Chicago

The testing of 8-year-old concrete is of itself sufficiently unusual to attract attention. Recent tests made at the Structural Materials Research Laboratory, Lewis Institute, Chicago, were unique in that the 8-year-old concrete specimens had been previously loaded to failure when 28 days old. After the original test, which did not shatter the concrete, the cylinders were thrown outdoors on the ground exposed to the weather.

The compressive strengths of five 6 by 12-in. cylinders, 1 part cement to 5 parts aggregate by volume are:

28-day strength—lb. per sq. in.	2330	2510	3130	2360	1580
Strength of same retested after 8 years	5070	4200	5290	4940	5980
Ratio of 2-yr. to 28-day strength, per cent (average 228)	217	167	169	210	379

The variation in strength was due to difference in the size and grading of the aggregates and in the consistency of the concrete.

The cracks which were caused by the 28-day test closed up during 8 years' exposure to weather. This may be explained by the slight solubility of both hardened cement and aggregate in rain water. Depositing of soluble compounds in the old cracks formed a good bond.

The writer has called attention to similar phenomena in the following instances:

(1) During the loading of a reinforced concrete test bridge for the Illinois Highway Commission, diagonal tension cracks near the ends of the girders which had been produced three years before by a preliminary test load (when the bridge was two months old) were carefully mapped and photographed. In the final test many of the old cracks did not reopen, although the load on the bridge was about six times the load which caused the cracks. For a detailed report see "Test of a 40-Fft. Reinforced Concrete Highway Bridge," Proc. Am. Soc. Testing Materials, 1913.

(2) Evidence of autogenous healing of early injuries due to overstressing in bond or compression will be found in "Tests of Bond Between Concrete and Steel," Bulletin 71, University of Illinois Engineering Experiment Station, 1913.

It is probably a new idea to most users of Portland cement concrete that in the presence of moisture, small cracks will heal and in fact become much stronger than before the break; it is reassuring to know that concrete possesses this remarkable property.

Concrete Beams

Reduction in the weight of hulls of concrete ships was a matter of importance during the war. Tests for the Emergency Fleet Corporation at the Bureau of Standards and at Lehigh University showed that by the use of sufficient steel reinforcement properly placed in the walls of the ship it was safe to make the shell only 4 or 5 inches thick instead of 12 to 15.

The probable value of the information in bridge and building construction as well as in ship work led the bureau to extend greatly the scope of the tests. This work has been completed and a technologic paper, Shear Tests of Reinforced Concrete Beams, is in preparation.

This paper gives results of tests on the resistance to shearing stresses of 172 reinforced concrete beams. Most of the beams were of I-shaped sections. This shape was necessary in order to provide sufficient resistance to the horizontal tensile and compressive stresses and at the same time permit the development of high shearing stresses in the webs.

The web stresses varied from 2 to 12 inches. Most of the beams had a depth of 36 inches and a span of $9\frac{1}{2}$ ft., or a depth of 52 inches and a span of 16 ft. The web reinforcement consisted in most cases of loose stirrups placed vertically or at 45° with the vertical. In all cases the bars were anchored to prevent bond failure. The strength of the concrete varied in different beams from about 21,000 lbs. to about 5,400 lbs./in.^{2}

One beam had a depth of 10 ft. and a span of 20 ft., and after it had been loaded 40 times to an intensity of shearing stress of 727 lbs./in.^{2} it was inverted and loaded to failure at a maximum shearing stress of 1,540 lbs./in.^{2} The repetition of the load had no apparent effect on the strength of the beam or on the stresses developed at high loads.

Very little tensile stress was developed in the web reinforcement of any of the beams before cracks appeared. Generally the cracks occurred at shearing stresses from 100 to 300 lbs./in.^{2}

The tensile stresses in the stirrups at any shearing stress were independent of the stress of the concrete. Diagonal compression failure occurred in some of the beams made from concrete of a lean mix and reinforced with vertical stirrups.

The shearing stresses, v (in pounds per square inch), in the beams are fairly well represented by the equation

$$v = (0.005 + r) f$$

where r is the ratio of sectional area of the stirrup to that of the concrete reinforced by it, and f is the tensile stress (in pounds per square inch) in the stirrup. This formula applies to the beams with either vertical or inclined web reinforcement.

Where vertical and inclined tension bars were present in the web of the same beam, the stress in the inclined bars was greater than that in the vertical bars for all stresses below the yield point. The maximum load carried was about the same as if the web reinforcement had been the same in total amount, but all vertical or all inclined.

Horizontal reinforcing bars in the web reduced the effective section to such an extent as to permit failure by horizontal shear in the web.

The deflection and crack widths were greater for beams with vertical than for beams with inclined web reinforcement.

Five Fellowships in Highway Engineering and Highway Transport

Fellowships to provide for the following researches to be conducted under the direction of the Division of Highway Engineering and Highway Transport of the University of Michigan have been renewed for the year 1925-1926.

Roy D. Chapin fellowship in Highway Transport; Roy D. Chapin fellowship in Highway Engineering, on hard surfaced roads and pavements; two Detroit Edison Co. fellowships in Highway Engineering, relative to moderate cost country roads; United Fuel & Supply Co. fellowship in Highway Engineering, on efficient methods of sampling gravel.

Trade your ideas for new ones through the columns of CONCRETE.

Graded Aggregate

Adhesion of Mortar to Brick

Comparatively little work has been done on the adhesion of mortar to brick, although it has been recognized that the bond between mortar and brick is a factor contributing to the strength and performance of masonry. The problem, therefore, of determining the effect of various kinds of mortars for use with sand-lime brick was taken up by the bureau.

The total absorption and rate of absorption have been determined for 1,100 sand-lime bricks, so that they can be arranged in groups of different absorptive capacities. In general, bricks of the highest total absorption show the most rapid rate of absorbing water.

Tests were made with a 1:3 cement mortar, where the percentage of water was varied, both in the bricks and in the mortar. Where the bricks were used dry, the mortar adhered to the brick first in contact with it. Where the bricks were wet, the mortar adhered to the second brick. The results show that the strength of the bond between cement mortar and bricks is greater when bricks are wet rather than dry and when the mortar itself is quite wet.

Hydrated Lime and Other Admixtures

A second edition of Bulletin 8, "Effect of Hydrated Lime and Other Powdered Admixtures in Concrete," of the Structurals Materials Research Laboratory, Lewis Institute, Chicago, has been issued. The paper was originally published in the *Proceedings* of the American Society for Testing Materals, 1920. Tables and diagrams have been revised to include 2 and 5-year tests.

This investigation was confined to powdered admixtures which are essentially inert in the presence of water and portland cement, as contrasted with liquids or soluble materials. Most of the tests were made with hydrated lime, but 17 other powders were also used. The effect was studied of admixtures up to 50% of volume of cement on the compressive and tensile strength, wear, bond and workability of concrete made with sand and pebbles and crushed limestone aggrgate of different sizes and gradings, in mixes ranging from 1:2 to 1:9, and a wide range in consistencies. Seven different investigations were made, including more than 20,000 tests at ages of 3 days to 5 years.

The principal conclusions are:

In general the strength of concrete was reduced approximately in proportion to the quantity of admixture. Some exceptions are noted below.

In usual concrete mixtures, each 1% of hydrated lime (in terms of *volume* of cement) reduced the compressive strength 0.5%; in terms of the *weight* of cement the reduction was 1.2%. The reduction in strength caused by *replacing* cement with an equal volume of hydrated lime was about 1¾ times that caused by adding lime. High calcium and high magnesium limes produced the same effect.

The addition of 1% of the following powdered admixtures in terms of the *volume* of cement *reduced* the strength of 1:4 concrete at 28 days by the following percentages: clay brick, 0.08; clay, 0.22; whiting, 0.24; sand, 0.37; natural cement, 0.38; limestone, 0.39; lava, 0.40; fluorspar, 0.43; kaolin, 0.47; kieselguhr (celite), 0.48; tufa, 0.51; hydrated lime, 0.56; ironite, 0.60; yellow ochre, 0.68; mica, 1.10; pitch, 1.50; gypsum, 4.00. For the same conditions the addition of 1% of portland cement *increased* the strength of concrete about 1%; granulated slag showed an increase of 0.12%.

Rich concrete mixes showed a greater loss in strength due to powdered admixtures than the leaner ones. In lean mixes (1:9 to 1:6) and those in which aggregates were graded too coarse for the quantity of cement used, the strength was little affected or was slightly increased by admixtures up to 50%. The wetter mixes showed a greater loss in strength than the dry, due to the hydrated lime. The effect of admixtures was in general independent of the age of the concrete.

Hydrated lime and other powdered admixtures slightly increased the workability of the leaner mixes (1:9 and 1:6) as measured by the slump and flow tests. Ordinary mixes (1:5 and 1:4) were little affected; richer mixes (1:3 and 1:2) were made less workable. Lime and portland cement (up to 33%) produced essentially the same effect on the "flow" of concrete.

The wear of concrete was not sensibly increased by hydrated lime or other powdered admixtures up to 20% of the volume of cement.

The bond resistance was affected in the same manner as the compressive strength by the addition of hydrated lime.

For usual concrete mixtures a reduction in strength of about 10% was produced by the use of hydrated lime in the percentages recommended by advocates of this practice.

Colonel Boyden Dean of Engineering at Ohio Northern

Col. H. C. Boyden, Chicago, national lecturer for the Portland Cement Association on subjects pertaining to the proper use of concrete, has been appointed dean of the engineering department of Ohio Northern University, Ada, Ohio. He assumes his new duties September 1.

Colonel Boyden, a native of Massachusetts, is a graduate of Worcester Polytechnic Institute, class of 1894. He is a member of the American Society of Civil Engineers and the Society of American Military Engineers. His engineering experience before the war consisted of railway and highway construction work in the eastern part of the United States and on the Pacific Coast. In the military service during the war he organized forces for the collection of military information in the United States. This work involved much travel and brought him into contact with many high state and government officials.

Since the war his lectures in all parts of the United States and Canada have extended still further his personal acquaintance. In this time he delivered over twelve hundred lectures to business men's organizations, colleges and universities, technical societies and clubs, and contractor's organizations.

Colonel Boyden's appointment is coincident with a program of expansion in the engineering department of Ohio Northern University. Particular attention will be given to instruction and training in the practical application of laboratory principles to field control of the quality of concrete. Other phases of the courses in engineering will be maintained at the usual standards.

Circulars issued by the Haydenrite Brick & Machine Co., 403 Security Building, St. Louis, Mo., describes Haydenite, a new unit. This unit as made up presents a face 2¼ in. high by 8 in. long—a brick face. This is one side of a unit of letter H shape, the center bar being a tile between two brick-like portions of the unit on either side of the wall.

New Books

Concrete Making Machinery, by W. Noble Twelvetrees, 178 pp;; size 5 in. x 7½ in.; price, 8 s. 6 d., published by Scott Greenwood & Son, London, England. D. Van Norstrand Co., New York City.

In this book, the author first defines concrete and discusses the selection, testing and preparation of materials used in concrete, paying particular attention to the machinery and plant available for testing as well as equipment for mixing, distributing and placing the product in the forms.

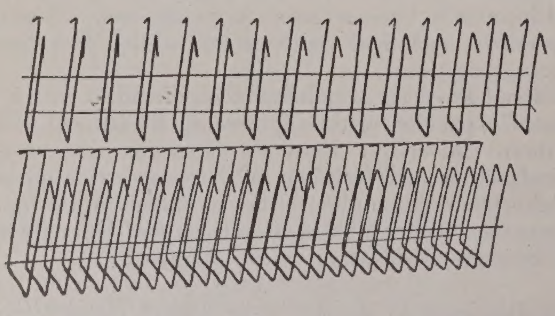
In discussing the preparation of materials for concrete, the author takes up the general equipment used for crushing, screening and washing, illustrating the discussion with typical sand and aggregate plants. Under the heading of mixing and placing the principles of the various types of concrete mixers are discussed and typical installations of placing equipment include towers and chutes, cement grouting machines and the cement gun.

Continuous Stirrups of Wire Mesh

A continuous stirrup which it is claimed reduces the field labor to a minimum in connection with beam wrapping in reinforced concrete construction has been brought out by Joseph T. Ryerson & Son, Inc., Chicago, Ill. Among the many advantages claimed for the continuous stirrup of wire mesh are uniformity of wire spacing, exact width, straight sides and ease of application for concrete protection for steel beams at sides as well as underneath.

This type of continuous stirrup is made from rectangular wire mesh which is furnished in rolls by the wire mills. The material is run through straightening rolls and then cut into sheets of sufficient width to include the two sides and bottom of the stirrup to be formed as well as the additional material required to form hooks at each side of the beam. The shearing is done so accurately that ends of the hooks after bending are in exact alignment and rest evenly on the wood forms at either side of the beam when placed in position in the field. The stirrups are formed in a machine and the sides and bottom are pressed to the desired depth and width with all corners straight and true.

When delivered on the job, the stirrups are dropped into position in the form and the main reinforcement inserted. When the bars are wired to the stirrups in two or three convenient places, the beam is ready for the pouring of the concrete. The stirrups support the main reinforcement at the proper height above the form and no other supports are required except in cases of long beams where the usual bar supports may be needed at the center of the beam.



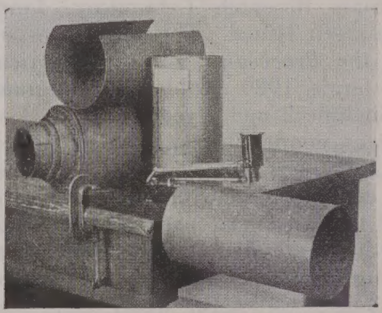
Continuous stirrups made from electrically welded fabric. In the upper piece the main wires are spaced 4 in. apart and in the lower 2 in. apart

Rectangular wire mesh is usually made with main and secondary wires each uniformly spaced, although the spacing may not and generally is not the same for both wires. Where the number of stirrups required is few or there are a large number of different sizes, or shapes, and but few of each kind, standard mesh having a spacing and size of main wires equivalent to the size and maximum spacing of individual stirrups is used, but where the quantity of any one size is large, wire mesh can be furnished having the main wires spaced close together at one end of the roll and with the spacing increased toward the other edge, providing the mesh equivalent in every way to that called for in a design having individual stirrups shown or specified.

Cyl-o-Con Molds for Concrete Cylinders

Cyl-o-con molds are cardboard forms for molding concrete cylinders used for strength tests on the job or in the laboratory. They are made by the Standard Concrete Apparatus Co., Washington, D. C., manufacturers of concrete testing equipment. They are stocked in two sizes, 6 in. diameter by 12 in. high, the size more commonly used, and 4 in. diameter by 8 in. high for use only where the maximum size of aggregate is under 1 in.

Cyl-o-con molds are shipped and handled in compact rolls of 10. The molds are slit lengthwise in order to allow them to nest one within the other. Just before use they are assembled by lacing with a stapling machine shown at the right in the accompanying illustration.



Cyl-o-con mold outfit showing stapling machine and roll of 10 nestled molds

In assembling the molds, the edges are brought together in a butt joint with the slit at the top. The staples are placed at right angles to and spanning the slit. One end is punched first and then the mold reversed and one or two staples put in the other end, making sure that the edges of the slit are close together and that both sides of the top and bottom edges of the mold are flush. Staples are punched half an inch apart the whole length of the unit, using 25 in all. During the lacing of the molds, one of the marking tags provided with the molds can be attached to the outside, one end of the tag being fastened with staples that span the slit. Identification number or other data can be marked on the tag with the waterproof crayon that is included among the stapling machine accessories. In cases where very wet mix is to be molded, the slit joint can be sealed and made completely watertight by holding a lighted candle inverted and allowing the drippings to seal the inside of the slit. Unless the mix is very wet this sealing is unnecessary.

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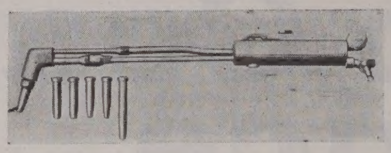
Milburn Low-Pressure Torch

A low pressure torch which will operate on either low pressure or high pressure gas with equal efficiency has been put out by the Alexander Milburn Co., Baltimore, Md. It is especially constructed to operate with low pressure acetylene gas, city gas or hydrogen. It utilizes the highly specialized and standardized parts of the Milburn cutting and welding torches.



Milburn low pressure combination cutting and welding torch

This torch is designed to perform welding as well as cutting work by tte mere interchange of tips.

It is of bronze forgings and special seamless tubing, constructed to withstand constant service. The tips are made of solid copper and are interchangeable with a large number of low pressure torches of other makes.

Trade Publications

C. H. & E. catalog has just been issued by the C. H. & E. Manufacturing Co., Milwaukee, Wisc., and contains 150 pages of information on saws and saw rigs, diaphragm pumps, centrifugal pumps, triplex pumps, hoists, mortar mixers and elevators.

Specifications for Truscon Waterproofings, Dampproofings, Oilproofings, is the title of Book A of a series of booklets issued by the Truscon Laboratories, 8½ x 11 in., arranged for vertical filing and containing specifications as indicated in the title for the use of Truscon products. It is gotten up in such a way as to make an easy reference publication for filing.

A new sand and gravel handling equipment book No. 540 has just been published by Link-Belt Co., of Chicago, Indianapolis and Philadelphia.

This is a 72-page book intended for the use of those who are interested in the latest designs and the most modern methods used in the production of sand and gravel.

Descriptions and illustrations of various types of screening, washing and handling equipment used in the preparation of sand and gravel are included. Systems of washing are shown, as well as the application of elevators, belt conveyors, vibrating screens, crawler and locomotive cranes, and both drive and conveyor chains.

The Truscon Laboratories, Detroit, Mich., has yielded to the popular idea in issuing a series of crossword puzzles. This is, of course, an advertising stunt, and for people in the building field it will give them puzzles for their special consumption, and provide them with information about Truscon Laboratory products.

Wire Rope for Guard Rails is the subject matter of a circular issued by the American Steel & Wire Co.. 208 S. La Salle St.. Chicago, describing and detailing the use of cable guard rope as increasingly used for highway guard rail.

Durable Paving in the Railway Area is the title of a new folder from W. S. Godwin Co., Inc., Race and McComas streets, Baltimore, Md., carrying an illustrated article about Paving Troubles Along the Rail, causes of and suggested remedies.

R. C. building units are described in a booklet recently issued by the R. C. Products Trust, Cleveland, Ohio, and numerous uses for the precast reinforced concrete beams are illustrated. The R. C. building units are factory made reinforced concrete units for which it is claimed that the steel is accurately and positively positioned in a concrete mixture of properly graded materials. The beams are recommended as being of known definite strength standardized of uniform height, irrespective of span or load. No forms are required and it is claimed that the units are readily shipped and placed.

Standard specifications for R. C. beams in buildings and for R. C. beam crib and retaining walls are included in the booklet.

A new wall covering for interior and exterior use recently put on the market by the Louisville Cement Co., Louisville, Ky., under the name, Walsment, is described in a leaflet just issued by the Louisville company. Walsment is described as a mortar material for covering both exterior and interior surfaces of walls. It is a plastic combination of cement, which, when applied, is practically impervious to water and may be employed in situations where other plasters are not efficient, for dampness does not cause it to scale or disintegrate. It is claimed for the product that it lends itself to any kind of finish desired.

R. I. W. Colored Integral Hardener is the subject of literature distributed by Toch Brothers, New York City. It is a product, according to the producers, combining the advantages of a coloring material with a hardening, densifying medium which also possesses waterproofing properties. It is sold in paste form and is furnished in terra cotta, red, brown, willow green, sea green, dark slate, and other alkali-proof shades. Special shades are made to order.

The Hume Pipe is the title of a very attractive piece of catalog literature, issued by the American Hume Concrete Pipe Co., United Savings Bank Building, Detroit. This literature presents a review of the Hume process, which originated under patent rights owned by the original Hume Pipe Company of Australia, and which has been used extensively in Australia, New Zealand, and England. The American rights were recently acquired by the new Detroit company. Hume pipe is used for water mains, sewers, culverts, conduits and other engineering applications. Hume pipe is produced by the centrifugal process, which gives unusual density and clean, smooth surfaces.

Organizations

American Concrete Institute; Harvey Whipple, Secretary, 1807 East Grand Blvd., Detroit.

American Concrete Pipe Association; M. W. Loving, Secretary, 111 West Washington St., Chicago.

American Engineering Standards Committee; Dr. P. G. Agne, Secretary, 29 West Thirty-ninth St., New York City.

Associated General Contractors of America; G. W. Buchholz, Secretary, 1038 Munsey Bldg., Washington, D. C.

Associated Metal Lath Manufacturers; 123 West Madison St., Chicago; Wharton Clay, Commissioner.

Building Officials Conference; Rudolph P. Miller, President, Fred W. Lumis, City Hall, Springfield, Mass., Secretary.

Concrete Reinforcing Steel Institute; M. A. Beeman, Secretary, 160 North La Salle St., Chicago.

Iowa Cement Stave Silo Association; H. E. Kilmer, Secretary, Oskaloosa, Iowa.

Iowa Concrete Products Association; Ross Dowell, Secretary, 405 Hubbell Bldg., Des Moines.

Mid-West Concrete Products Association; D. R. Donlen, Secretary-Treasurer, 4340 Marcy St., Omaha, Neb.

National Association of Manufacturers; John E. Edgerton, President; Henry Abbott, Treasurer; George S. Boudinot, Secretary, 50 Church St., New York City.

Ohio Concrete Products Association; G. M. Friel, Secretary-Treasurer, 2284 North High St., Columbus, Ohio.

National Crushed Stone Association; A. P. Sandles, Secretary, 405 Hartman Bldg., Columbus, Ohio.

National Housing Association; Lawrence Veiller, Secretary and Director, 105 East Twenty-second St., New York City.

National Sand and Gravel Producers' Association; T. R. Barrows,

The National Lime Association; Mather Bldg., Washington, D. C. Acting Secretary, 903 Munsey Bldg., Washington, D. C.

Portland Cement Association; William M. Kinney, General Manager, 111 West Washington St., Chicago.

Wisconsin Concrete Products Association; D. R. Collins, Secretary-Treasurer, Milwaukee.